

T H E
P R I N C I P L E S
O F
A G R I C U L T U R E
A N D
V E G E T A T I O N.

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T H E
D E S I G N.

THE *Edinburgh* society, established in the year 1755, for the improvement of arts and manufactures, named, amongst other articles, the following :

For the best dissertation on vegetation and the principles of agriculture, a gold medal.

IN order to promote so useful an institution, the following papers were composed, and delivered in to the society, according to the rules laid down. The judges named for that article, determined, on a competition, in their favour. Some few ad-

ditions have been made to them since they were given in to the society.

IN so necessary an art, where the terms are inaccurate, confused, and differ so much in different counties, to fix these terms, and ascertain their meaning ; where there is nothing systematic, to lay down a regular plan ; where the different parts are generally looked on as complete, to mark the deficiencies, and show that there is much wanted ; where the means of improvement are unknown or neglected, to point out the only road that can lead with certainty to it ; where there are few experiments to build on, to relate some, and on these to lay a foundation for more ; where the reasonings are, in general, so very unphilosophical, to settle some fund for discourse and argument ;

ment ; where the proper helps have not been called in, to make use of these, and introduce a new science to the assistance of this art ; in short, where there is but little ascertained, to fix some general principles on which the artist may depend : This is the design of the following papers. That no more has been done, will be most readily excused by those who are best acquainted with the difficulty of the undertaking.

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T H E
P R I N C I P L E S
O F
A G R I C U L T U R E and V E G E T A T I O N .

P A R T I .

S E C T I O N I .

*Causes of the slow progress of agriculture ;
connection of chymistry with it ; and divi-
sion of the subject.*

AGRICULTURE, though the most
necessary, has been, perhaps, the
most neglected of all the arts. Every
other art has undergone considerable im-
provements in this and the last century ;
but we cannot affirm the same of agricul-
ture. It seems to be little better under-
stood

stood in *Europe* at present, than amongst the ancients ; and I believe *Virgil* and *Collumella* may still be reckoned the best authors on that subject. Does this proceed from the earth losing, like a mother, her fertility, because of her age ? as some of the ancients alledged ; or does it arise from an impossibility of reducing the culture of the ground to a regular art, as the effects of that culture depend more on chance than settled principles ? Daily experience shows that none of these can be the case : for the earth, though exhausted, attains again, under proper management, a great degree of fertility ; and the regularity with which affairs are conducted, shows, that it is in some measure already reduced to an art.

THE slow progress of husbandry may be accounted for from more obvious reasons. This art is, in general, carried on by those whose minds have never been improved by science, taught to make observations, or draw conclusions, in order to attain the truth ; or by those who, although

Nature

Nature has been very bountiful, cannot carry their schemes into execution, from the narrowness of their fortunes. The former can never know more than what they have learned from their fathers; the latter dare risk nothing, as their daily bread depends on the certainty of success. What can be expected from that class?

LET us suppose the fortune easy, and the judgment improved, the difficulty of the art itself is sufficient to retard its progress. How delicate the circumstances that must attend each experiment! What a number of different observations on heat and cold, dry and wet, difference of soils, grains, seasons, &c. must be exactly made, before one can be certain of the general success of an experiment! What a disagreement from a small difference in one of these circumstances! How seldom can these experiments be repeated, which take a whole year before they can be brought to a conclusion! how unequal for such a task are the few years of judgment and activity

we enjoy ! How liable are observations to die with the observer when not made public ! and how averse is human pride to do it, unless it could erect a system ! Agriculture, seemingly so easy, appears, from the scarcity of good authors, to be the most difficult of all arts.

BUT these are not the only obstacles that husbandry has met with. It has yet had a greater to struggle with. It does not, like most arts, lead to an account of itself ; or depend on principles which its practice can teach. Something beyond this art is necessary to the knowledge of the art itself. The principles of all external arts must be deduced from mechanics or chymistry, or both together. Agriculture is in the last class ; and though it depends very much on the powers of machinery, yet I'll venture to affirm, that it has a greater dependence on chymistry. Without a knowledge in the latter science, its principles can never be settled. As this science is but of late invention, and has not yet been cultivated
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with that regard to utility, and the improvement of trades and manufactures, as it ought and might, agriculture is hardly sensible of its dependence on it. The design of the following sheets is to make this appear; and to try how far chymistry will go in settling the principles of agriculture.

I don't intend in the following remarks to settle facts, or teach the practical part of farming. That I leave to farmers. My design is only to sketch out the great outlines of this art, and show, that it is capable of being reduced, like others, to a regular system. If in this way we can fix some settled principles from the facts which are already ascertained, those who apply to practice will find their benefit in it. The just theory of an art leads directly to its improvement, as it leads to those experiments which yet remain to be tried. Without this guide we may stumble on truths by accident; but when led by it, we have the secret satisfaction of thinking, that we are,

indebted to ourselves for the happy issue of the experiment.

LET us try to find some fixed point from which we may have a full view of this extensive art, and from which we may proceed, in a methodical manner, to the division of our subject. All organized bodies receive their increase from the reception and application of certain particles, which are designed by the Author of nature for their nourishment. Without these nutritive particles there could be no increase. As plants belong to the class of organized bodies, they thrive in proportion to the quantity of nourishment they receive at their roots. Hence arises a simple, but very comprehensive, view of husbandry. The whole of the art seems to centre in this point, *viz.* nourishing of plants.

BUT how can the farmer understand the art of nourishing plants, unless he knows the nature and qualities of each kind of soil, whether it be proper or improper for

for that office ; unless he can provide suitable food for the nourishment of plants, and discovers what that food is ; unless he assists the plants in reaching and acquiring that food, by rendering the soil loose and open ; unless he knows, and endeavours to remove, so far as lies in his power, all impediments to this nourishment ? These are the great outlines of agriculture. In following these, then, we shall divide our subject into five parts. 1. The nature and qualities of different soils. 2. The nature and qualities of the different composts. 3. Their manner of acting. 4. The different methods of opening the soil. 5. The impediments to vegetation, and their cure.

THE operations of bodies are to be accounted for only from their known qualities ascertained by experiment. Reasoning on any other plan, can never certainly lead to truth. I shall not, therefore, proceed a single step without fact and experiments ; and when I am not supplied with them
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from others, shall endeavour to make them myself. It is laborious, but it is necessary.

S E C T. II.

Of different soils.

AS the earth is the matrix to which all seeds are committed, and from which all vegetables take the whole, or at least the greatest part of their nourishment, it is proper to begin with an examination of it. As it nourishes plants without the assistance of art, it must contain the food of plants. If we can discover what is the natural food of vegetables, we shall the easier discover wherein consists their artificial food or that given by art, and how it operates.

EARTHS are found to differ very much from one another in their qualities; farmers have therefore divided them into several different kinds, and perhaps have
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run into too minute divisions. It is difficult indeed to settle the exact limits betwixt the different soils ; but such difficulty we find in all the divisions of natural bodies. The Author of nature has connected different bodies by intermediate ones ; he has chosen to act by different gradations, and not by starts, that nature may appear one connected whole. The great division, or the specific differences of earths, may be reduced to these six, *viz.* rich black soil, commonly called *loam* or *basley* soil ; clay ; sandy ; mossy ; chalky ; and till.

WHEN farmers treat of these soils, they generally distinguish them from one another by the colour, or some other superficial quality, which immediately strikes the senses. But colour can never lead to the composition or principles of bodies, on which alone their effects depend. Such superficial qualities as that, depend themselves on the constituent parts of bodies. We shall then endeavour, by experiment, to

to detect the constituent parts of these different soils, and show wherein they differ from one another.

S E C T. III.

Of the rich black soil.

I Begin with this soil, as it is found to contain the greatest quantity of vegetable food, and as all other soils are richer or poorer in proportion as they contain more or less of this.

THIS soil, when fresh dug up, and sufficiently moist, has a very agreeable smell, which is not felt when it is too dry or too wet. We are very sensible of an agreeable smell in the fields after a gentle shower of rain, especially if a drought has preceded. This we attribute to the effluvia of the plants; but it belongs to the earth, as it is to be felt every where, and stronger the nearer the nose approaches the

the ground. This is probably owing to the volatile salts and oils, which rise together, in greater plenty, as the natural fermentation of the earth is increased by a due proportion of moisture.

To crumble when dug up, is a quality peculiar to this soil. In this it differs very much from the clay and sandy soil. The former does not separate; the latter falls into a powder like sand; but this separates into small bits. It seems to enjoy that degree of cohesion which is fittest for supporting vegetables, and at the same time allowing their fibres to spread in search of their food. The particles of this soil seem to be in a continual tendency to recede from one another; for it is observed, that when dug up, and exposed to the air, the hole from which it was taken, will not again contain the quantity taken out. This must be owing to a fermentation of the putrefactive kind, carried on, in a small degree, in these rich soils, whenever the air is admitted to them: for without air there

there can be no intestine motion. This continual tendency to putrefaction, in some of the particles of this soil, will appear more plain from its colour, and quantity of oil, the only subject of corruption. Hence it follows, that there must be a degree of heat in this soil, in proportion to the progress of the putrefactive fermentation, and independent of the sun, or natural heat of the internal parts of the earth.

THIS soil admits the water easily, and swells like a sponge after it has taken the moisture in. This quality is peculiar to good soil. It contracts again when dried. Hence naturalists conclude, that this soil consists of spongy and swelling particles. I rather chuse to attribute this swelling to the fermentation, or intestine motion, which continually goes on in this soil, being increased by the addition of the water; for all bodies must have a certain degree of watry particles, in order to make the fermentation go on properly.

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It is observed of all soils, the mossy and boggy ground excepted, that the blackest are the richest. This colour gives us a strong presumption, that these soils contain much fat and oleaginous matter; for all fossil and vegetable oils, when they have a great admixture of earth, are of this colour. It is owing likewise to these oils, that all vegetable or animal substances gain a black colour when in the road to putrefaction. The unctuousity too of this soil, a quality of it which is remarked by farmers, is a proof of its oleaginous nature. This black colour will make it reflect fewer of the sun's rays, and so make it susceptible of a greater heat, than soils which are of a lighter colour.

BUT we have a certain method of knowing, whether a body contains any oleaginous particles or not, by the means of nitre melted in the fire. Nitre, though not inflammable of itself, becomes, in this situation, inflammable, or, as the chymists chuse

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to call it, deflagrates with bodies which contain any oily particles.

Exp. 1. Some rich mould taken up three or four inches deep from the border of a garden where no dung had ever been laid, deflagrated very much with nitre in fusion. Hence it appears, that this soil contains much oil.

To discover if this earth contained any absorbent or alkaline particles, I tried the following experiment.

Exp. 2. Some strong vinegar, diluted with twice its quantity of water, being poured on this fat earth, raised a gentle fermentation, from whence many air-bubbles arose; the acid taste was at last destroyed, and the vinegar reduced to a neutral body. From this experiment we learn, that rich mould contains a great many particles which attract acids, and with them make a neutral salt. I have learned from many different trials, that all soils fit for the nourishment

rishment of plants, contain more or less of these antacid particles.

To discover what we should get from this earth by distillation.

Exp. 3. I distilled half a pound of it with a gentle heat ; I got in two hours an ounce of a yellow empyreumatic liquor, which was of an alkaline nature. The strongest fire continued for nine hours longer, gave half an ounce more of a yellowish empyreumatic liquor, which had several oleaginous filaments swimming in it. It smelt like spirit of hartshorn, turned fyrup of violets green, and effervesced strongly with vinegar.

FROM this experiment it appears, that the salts of this soil are of the volatile alkaline kind ; and that these salts naturally exist in it, as they rise with a small degree of heat. From this likewise we have another proof of oil being contained in this soil, as it tinged the first water with a yellowish

lowish colour, gave it a burnt smell, and was plainly to be discovered in the second floating about in a filamentous way.

S E C T. IV.

Of the clay soil.

THE clay soil is very different from the former; and as it is a composition of clay with a mixture of the former soil, we shall inquire into the properties of clay.

THE distinguishing and characteristical property of this body is, that having already got a certain quantity of moisture, it resists, in some measure, the entrance of more water into its pores, is very slowly penetrated by that fluid, and therefore is not in any great degree softened, loosened, or otherwise affected by it. Clay, when pressed by external force, or firmly compacted by

by its natural subsidence, as we find it at the bottom of many of our soils, and of most of our mosses, will even sustain water, and become impenetrable to it. Hence soils, in proportion to the quantity of clay they contain, will hinder the water from passing through them; will keep the vegetables continually soaked in moisture; will not be so much heated by the rays of the sun as if they were dry; and, therefore, are justly deemed of a cold nature.

WHEN exposed to the degree of heat of a summer sun, clay dries, and turns very hard, so that it requires a considerable force to separate its parts. This quality of clay is the more observable, if it has been full of moisture, and dried suddenly. Hence clay grounds are so apt to cake with heat, especially if they have been ploughed wet, and will, in that state, hinder the roots of vegetables from passing through them.

THESE qualities of clay seem to depend on the same cause, *viz.* the strong adhesive

power of its particles. Its great ductility shows, that its particles adhere very firmly. But whence this adhesion? Is it from a certain figure of its particles, by which they are intangled, and cannot be so easily separated? or is it from oleaginous particles mixed with the earthy, as we know that oil is adhesive, and rejects water? I incline to the latter opinion, as I have found that clay contains an oil, not so loose indeed as in the former soil, but intimately connected with its earth, and scarcely separable from it.

Exp. 4. I mixed some clay with vinegar; but there was no fermentation, and the acid taste was not blunted. It seems then to have neither alkaline nor absorbent particles in its composition. In this it differs very much from the former soil.

CHEMISTS generally assert, that clay contains an acid of the vitriolic nature, and an oil. From this acid they account for its distilling the acids of nitre and sea-salt, and

and for its vitrescible nature, as salts are the great assistants of vitrification.

LE MERY le fils, in the *Mem. acad. de Scienc. pour l' année 1708*, has these words. *Comme il y a dans l' argille de parties huilleuses, acides, et terreuses.* And again, *Car en la poussent par une feu plus considerable, il s'en échappe des acides et de parties huilleuses.* Let us see how far this is true.

THAT I might discover its contents by distillation,

Exp. 5. I put into the retort half a pound of dry clay, taken up seven feet below the surface from a clay-pit then employed in a brick manufactory; and as much sand was mixed with the clay, it seemed to be of a pure nature. After it had been distilled for two hours with a gentle fire, I got half an oz. of pure water. After it had suffered the strongest heat that I could give it in a portable furnace for nine hours, I found in the receiver two drams of a pellucid liquor, which

which smelt like the spirit of hartshorn, effervesced strongly with vinegar, and turned syrup of violets green. The remainder was very red.

Thus, instead of getting an acid, as the chymists assert, I have got an alkaline volatile spirit. No oil appears from this experiment; and, therefore, we may conclude, that if there is any oil in it, that oil is intimately united and combined with its earthy parts, analogous to what happens in metals.

THAT there is such an oil, several reasons induce me to think; its nourishing vegetables, which require oil, when opened by mere sand; its unctuousity; its igniting, like metals, when put in the fire.

Exp. 6. I tried such clay as I used in the former experiment with melted nitre. When small pieces were put in, no fire was produced betwixt it and the nitre: but I evidently perceived sparks of fire when it
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was put in powdered. Hence I conclude, that clay contains an oil intimately and closely combined with its terrestrial parts.

THE oleaginous nature of clay is clearly demonstrated by an experiment of Mr Eltors, in the 5th Vol. of the Berlin Memoirs. He boiled some clay in an alkaline lye; this lye when decanted was saturated with ol. vitriol. After the liquor had stood some time, he found at the bottom a viscid matter which deflagrated with melted nitre, and reduced the calx of lead to its metallic form. By this experiment the oil was got in a separated state from the earthy parts, which after this separation had lost their tenacity. This gentleman's experiments show us how strongly the oil and earth adhere; for the oil was scarcely separable by spirit of wine.

Exp. 7. When a piece of the clay was kept in the kitchen-fire for some time, it turned red like a live coal, and when taken out, had a high red colour, which seemed
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owing to the particles of iron that it contained. Very few particles indeed were attracted by the magnet. But it must be remembered, that this quality depends upon the inflammable part of that metal, which is always given it by art, and that I had not added oil in the calcination. Very few ores have this quality naturally. All these experiments were made on the same clay.

S E C T. V.

Of the sandy soil.

THIS soil gets its name from the quantity of sand which it contains. The qualities of this soil depend on the qualities of sand. This body differs much from the two former; from the latter, as it easily admits the entrance of water; from the former, as it does not detain the water like it, which seems to attract moisture with considerable force, and to resist its escape again; while

while sand allows it to pass easily through its body, and does not swell, but, on the contrary, turns less in bulk, when wet. Sand cannot detain the water so long as the rich soils, because it does not contain those saponaceous and mucilaginous juices which these do, and with which the water is combined and detained. Hence sandy soils often want a sufficient quantity of moisture for the nourishment of plants. Hence they are very hot, because sand is susceptible of a greater heat from the influence of the sun, and will retain it longer than water does.

SAND cannot swell by the addition of water; because that quality in rich soils is owing to an intestine fermentation, which goes on in them. But in sand there are no particles, and in sandy soils too few, which are capable of fermentation. Hence a defect of nutritious particles in sandy soils. Instead of swelling, it diminishes in bulk when wet; because the water rushing in, disposes the particles more regularly, so that

that the interstices are better filled up than before, and its bulk lessened.

THE faults, then, of the sandy soil are, that it lets water pass through it too easily, and that it contains too few nutritious particles. Whatever compost is used to this soil, must correct one or both of these faults. Clay will help it to retain the water; but then it is not richly stored with vegetable food. Woollen rags answer both purposes very well, as they contain a great quantity of mucilaginous juice, which serves equally well in nourishing plants, and in detaining moisture.

THE compost that appears to me to be one of the fittest is moss: for it is as impervious to water as clay, nay perhaps more so; and as it is a vegetable, contains more oil than any other that I know. This reasoning is confirmed by fact. A gentleman laid some of this manure on a small part of a field, consisting of a very light sandy soil. The oats which grew that year, and

with dung. No. 13. was the light poor sandy soil without any addition. No. 14. had the usual quantity of lime added to the soil. No. 15. had the usual quantity of dung added to the soil.

July 2. No. 1, 2, 3, 4, 5, 6, are all bad. No. 7. very good. No. 8, 9. exceeding good. No. 10, 11. very bad. No. 12. exceeding good. No. 13. is the worst of all, and scarcely bears any thing. No. 14. bad. No. 15. pretty good.

August 13. No. 1, 2, 3, 4, 5, 6. bad. No. 7, 8, 9. exceeding good and heavy grain. No. 10, 11. are all withered. No. 12. exceeding good. No. 13, 14. carries nothing. No. 15. pretty good.

FROM this experiment the following useful conclusions arise.

Corol. 1. A poor sandy soil, when of itself it was able to produce no grain in a dry season, was fructified to a considerable degree by dung alone; but clay alone, and lime alone, did it but very little service.

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Cor. 2. Light sandy soil is not much benefited by a mixture of clay and lime; but clay and dung enrich it to a prodigious degree, and make it capable of bearing a dry season, which of itself it can so little stand. While all vegetation was stopt in the soil alone, an addition of clay and dung produced one of the best crops that I ever saw.

Cor. 3. Though these conclusions agree in general with regard to all sorts of grain, yet as different kinds were sown, I observed that oats agreed better with clay, and clay and lime, than either barley or pease; but that the two last agreed better with the clay and dung than the oats.

SAND, however hard it is, seems to be mostly composed of a mucilaginous, oily substance; as appears by the following trial.

Exp. 9. February 9. I put 10 grains of pure sea-sand, pounded in a mortar, into a phial

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with one drachm of oil of vitriol; the same quantity of sand with the same quantity of spirit of nitre, in another glass; the same with spirit of sea-salt, in a third. *March 28.* the acids appeared turbid. I mixed with each some water, that I might get the sand easier away by itself, and that the particles mixed with the acids might be more easily separated. The sand in the first glass weighed 7 gr.; and that in the second and third, $6\frac{1}{2}$ gr. That I might precipitate from the liquors whatever was dissolved by the acids, I mixed with each as much pearl-ashes as was necessary to saturate the acids. After the effervescence was over, there was a brownish oozy powder at the bottom of the *ol. vitriol.* and an oily substance at the bottom of the other two, which was quite distinct from the water. What was precipitated from the spirit of nitre, was yellow; from the spirit of salt, was white. The former, when separated from the water, deflagrated with melted nitre, which showed it to be of an oily nature; but the latter did not. I must observe here, that the fine powder

powder of flint has a sensible deflagration with melted nitre.

As lime is a powerful diffolvent, especially of oily bodies, I imagined that lime might have some such effect on sand, dissolve it into a mucilage in the earth, and in this way sand might be converted into a fit nourishment for vegetables. This perhaps might be, I thought, the reason why lime and sand took so firm a bond together, when lime alone does not adhere. This appeared to me yet stronger, when I considered, that any mucilaginous or oily substance, such as whites of eggs, train-oil, &c. when mixed with quick-lime, make it take bond. I therefore tried the following experiment.

Exp. 10. I took a certain number of small pieces of flint, which is allowed to be of the same nature with sand, weighing 1 dr. $52\frac{1}{2}$ gr. and added a quantity of lime and water to them. They lay a-

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mongst the lime from the 9th of *February* to the 23d of *March*. When taken out, and dried, they weighed the same as when put in.

Exp. 11. That I might see what effect the mucilage extracted from sand by the acids, would have on quick-lime, I added a very small quantity of the mucilage from both acids to quick-lime, and baked them together into a paste. Some of the same lime was made into a paste with water alone. After they had lain for four weeks, and were entirely dry, neither of them had taken bond.

THESE experiments would seem to be in opposition to the former theory. The question, however, is of such use, especially with regard to building, that it deserves to be further considered.

S E C T.

S E C T. VI.

Of the chalky soil.

I SHALL say little about this soil, because; as it is to be found only in few counties in *England*, I have not yet met with it; and I shall relate nothing on the faith of those who reason without the assistance of experiment.

CHALK is an absorber of acids, and has no oleaginous particles in its composition, but is a powerful attracter of them. Hence the proper manure for this soil must be those bodies which contain most oil, as hair, rags, &c. It seems to have but a very weak attraction to water; and, therefore, will be generally too dry. This soil is observed by farmers to cake after heavy rains.

S E C T. VII.

Of till.

FARMERS call those soils *till*, which have a reddish, gray, or yellowish colour, are poor, will bear nothing, nor can be fertilized so easily or speedily as the former soils. Sometimes they render all attempts fruitless. This soil must, therefore, not only contain no vegetable food, but it must often contain a vegetable poison; else it would always become fruitful by the application of composts. What this poison is, must be the subject of our present inquiry; for unless we know it, we cannot know whether there is a remedy for it or not.

THE following experiments were performed on some of this unfruitful earth shown me by an experienced farmer.

Exp. 12. It effervesced visibly with vinegar and oil of vitriol diluted with water, but

but had a peculiar irony taste, and turned black with galls.

Exp. 13. Some of this earth calcined in a strong fire for two hours, was almost all attracted by the magnet.

Exp. 14. It did not deflagrate with melted nitre.

Exp. 15. Four ounces of brown till well dried, being distilled, in six hours gave two drams of a phlegm, which shewed no acid or alkaline nature.

FROM these experiments it appears, that this species of till contained neither salts nor oils, but was a composition of earth and iron. The poisonous quality of this soil must then have depended on the latter body, which we may observe by the first experiment is dissolvable in all acids, and in that state may enter the vessels of plants. We shall afterwards see that it will meet with

with acids. This reasoning is put beyond all doubt by the following experiment.

Exp. 16. I took one pound of good rich mould, and mixed with it one drachm of salt of steel ; put it into a pot, and sowed some barley in it in the beginning of *May*. Some of them shot up about an inch, looked very ill-coloured and sickly, and then died ; while other grains in another pot, filled with the same earth, throve very well.

THUS a very small quantity of iron, dissolved by the vitriolic acid, rendered a great quantity of rich earth unfruitful, and therefore ought to be looked on as the vegetable poison of till. If this poison can admit of a cure, I imagine it is only to be found in lime or marle, which will attract the acids from the iron, and make it, at least in a great measure, indissolvable in water.

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THOUGH the admixture of iron with the soil may be a very general cause of unfruitfulness, yet it seems not to be the only one. A great deficiency in some of the principles necessary for vegetation, must have the same effect. Thus farmers often give the name of *till* to indurated clays, and particularly to those which they find below the soil. The common farmer is afraid of stirring it up with the plough, because it is unfruitful: But the more judicious, willing to deepen his soil, takes it up by little and little, and finds that lime, dung, and air, readily fertilise it.

S E C T.

S E C T. VIII.

Of the Mossy soil.

I SHALL not enter into a discussion of the origin and nature of moss: It is now allowed by every body to be a vegetable substance. The following experiment is a proof of it.

Exp. 17. Half a pound of powdered peat gave me by distillation, during the two first hours, 2 oz. of an acid empyreumatic liquor, which was of a yellow colour, and showed its acid nature, by effervescing with *ol. tart. p. d.* The strongest fire continued for nine hours longer, gave me 2 dr. of a reddish empyreumatic liquor more acid than the former, and 1 scr. of a thick dark-coloured oil. There was besides about the neck of the retort, a great quantity of red oil, which was too heavy to come over. The *residuum* was black.

Exp.

Exp. 18. Some peat burnt in the open fire, gave me about the two and thirtieth part of alkaline salt.

HENCE we see, that peat affords the same principles as other vegetables do, and therefore must be classed amongst them.

THE only method, then, to make this soil fruitful, is to make the vegetable undergo a degree of putrefaction, by ploughing the soil, and so killing the plants. All vegetables turn to rich soil when they have undergone a degree of corruption; even oak bark becomes in time rich black mould. The parts will be the sooner separated, if some earth or clay is added to the moss; for moss of itself is rather an enemy to corruption. All kinds of vegetable substances and animal bodies are preserved uncorrupted for whole ages in moss-holes. Absorbents are known from experience to be promoters of corruption. The various kinds of marl,

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when they can be got, particularly the shell-marl, would seem to be the properest manures for this soil. Lime, as it appears to be a great dissolvent of all vegetable bodies, may have good effects on this soil.



P A R T

P A R T II.

S E C T I O N I.

The natural methods of providing vegetable food.

HAVING ascertained the properties of the different soils, the next thing we have to do is, to examine into the nature and properties of whatever is observed by experience to fructify ground, whether it be applied to the soil in a natural or artificial way. If we can discover some qualities in which all these manures agree, we shall arrive at the knowledge of what we are in search of, *viz.* the food of vegetables, or at least of those principles which go to the composition of that food. Let us first inquire into those ways by which nature fructifies the earth.

IF earth is exhausted of its vegetable food, experience has discovered, that it recovers it again, if allowed to lie idle. This shows, that the vegetable food is continually on the increase, when the earth is not robbed of it by the crops it bears. We discover immediately whence this food comes, when we attend to these two facts; that the more the soil is exposed to the air, the vegetable aliment is the sooner procured, and in greater quantity too; and that when the surface is buried by the action of the plough, and a new soil brought up, that soil, though seemingly as good as the former, produces bad crops, till it has received for some years the benefit of the atmosphere.

FALLOWING is a constant proof of this. The soil is frequently broke down and turned over by means of the plough, and every part of it is exposed to the influence of the air. That the communication of the earth, by the mechanical action of the plough, is not the chief means of increasing

ing the vegetable matter, as *Tull* asserts, appears plainly from these two facts ; that even the lightest soil is the better of fallowing ; and that when fallow ground is laid up in ridges, more benefit is received than when it is left quite flat.

BUT this nutritious influence of the air is yet more observable in those earthen dikes or walls made of the soil taken from the surface, and thrown up to inclose the sheep-folds. These dikes are exposed to the influence of the air, which passes through and through them for many months. The soil thus exposed is rendered prodigiously fruitful, so that it is easily distinguishable by the quantity and deep green colour of the grain, from the internal parts of the fold, which have been well manured by the urine and dung of the sheep. It is likewise remarked by farmers, that the earth of the dike lasts for three or four years longer fruitful than the other part of the sheep-fold.

THIS chief instrument, then, that nature makes use of to enrich the earth, is the air. Even the richest soils require its continual influence. On what principles of the air this fructifying quality depends, we cannot inquire, until we have ascertained the nature of the different manures which seem to operate by attracting those principles from the air. The strong and lasting vegetative power which the air communicates to the earth, should teach us to make a greater use of its influence than what we do. Why should we not raise the whole surface into fold-dikes? Other manures do not operate till the second or third year after they are laid on; this operates immediately. A farmer cannot, at a medium, dung an acre under 5 *l*; this might be done for 30 *s*. Dung fills the ground with weeds; this method cleans it. Manures cannot be found every where; this practice may be followed in all places. It would be particularly good for clay ground, as the vicissitudes of the air pulverise greatly.

DEW

DEW is reckoned by farmers a great fertiliser of the earth. It arises from the perspiration of the earth, of vegetables and animals in a sound state, and their exhalations in a corrupted one. The earth retaining its heat, after the sun's influence is weakened, elevates these attenuated particles; but the air cooling sooner than the earth, from its rarity, condenses them at a little distance from the surface; and those which become specifically heavier than the air, fall on the earth again. Hence dew must differ according to the difference of the bodies from which it proceeds. Its contents are therefore various; but experiments have discovered, that it is composed in general of oils, salts, and a great proportion of water. Of what use these principles are to vegetation, we shall afterwards see.

RAIN-WATER, especially in the spring, has nearly the same contents. Margraaf, in the *Academ. de Berlin*, vol. 7. has analysed it with great accuracy, and showed that

that it contains a nitrous and a sea-salt, with a considerable quantity of an absorbent earth; which probably was united to a nitrous acid before evaporation, and consequently increased the quantity of nitrous salt very much. The salts were of a brown colour, which discovered its oil. As the water was gathered in the winter, it contained a smaller proportion of this last body, than if it had been gathered in the summer.

Snow is justly reckoned amongst those bodies which fructify earth. I have observed a light floating oozy sediment at the bottom of snow-water, after I had kept it three or four days. When snow melts, its surface, even in the tops of hills, is covered with a brown powder. Both rain and snow water putrify sooner than spring-water; which shows that they contain more oily particles than it does.

Exp. 19. A pound and an half of snow-water being evaporated, gave 2 dr. of a
reddish

reddish liquor, which had little taste, and discovered nothing saline in it. I set it in a cellar for fourteen days; and when I took it out, it was covered with a mouldy substance. This mould, when dried, burnt on a red hot iron to a powder. Hence it appears, that snow contains an oily substance. Margraaf having evaporated a greater quantity of snow-water, discovered the same salts and earth as in rain-water.

THE overflowing or water-flooding of low grounds may be reckoned amongst the natural methods of improving the soil; because flat meadows are often naturally overflowed, either by rains, or by the rain-water falling from the higher grounds. *Egypt* is naturally overflowed once a-year by the *Nile*, and rendered by that means exceedingly fertile. Spring-water is even found to be of service to ground, but not so much as river-water, especially such as has run through a fertile country, and is, at that time, full of the subtiler particles
of

of the soil washed off from the rich grounds by rains. As these waters are impregnated with the subtile earth, and the saponaceous juices of those soils over which they have run, when they stagnate, these nutritious particles subside, and enrich the ground. The river *Nile* deposits a rich oozy mud, which is so full of putrescent particles, that its steams seems to be the cause of the plague raging so much in *Egypt*. By this addition of soil it receives every year, the level of the ground is considerably higher than it was. Hence too the vallies in all countries are much richer than the rising grounds; as the rains wash great part of the vegetable matter from the latter, and leave it in the former.

ART often imitates nature in this method of improving land, and lets in the streams of rivers to cover the fields. This is most frequently done in the spring, when these waters are most impregnated with nutritive particles. This water after it has
deposited

deposited all its particles, which it does in four or five days, is let off quickly; lest, by gradual evaporation, it should cake the ground, and hinder the grafs to come up; which is the great danger attending it, and for which it is thought improper for clay grounds.

It must be observed here, that there are some waters which are extremely prejudicial to grounds, such as coal and steel waters. This is owing to the quantity of iron which both these contain. All sulphur waters are likewise hurtful to ground; we shall afterwards see that sulphur is a poison to plants.

S E C T.

S E C T. II.

Of manures, or the artificial methods of providing vegetable food.

EXPERIENCE has shown, that certain substances, committed to the earth under certain regulations, make it more fruitful. These substances belong either to the fossil, the vegetable, or the animal kingdom. The fossil include the different kinds of marl; calcarious stones, such as lime-stone, chalk, &c.; and quick-lime. The vegetable include all vegetables, and their juices, either in an entire or a corrupted state; the ashes of burnt vegetables; the oils extracted from vegetables and foot. The animal include calcarious shells, entire or corrupted; horn-shavings or tips; wool-len rags; and all animal substances, such as dung, urine, &c. I shall treat of these in their order,

I am not to lay down the method of using these; I shall take no notice of that, but where it tends to show their method of operating. My design is to take a view of those qualities belonging to them, by which they are capable of operating on the foil, and producing certain effects on the vegetation of plants.

S E C T. III.

Of Marl.

THIS is a fossil body which feels unctuous and fat betwixt the fingers ; and resembles clay in a great measure, in-
somuch that marl, though a very different body, is often confounded with it. It is di-
vided into many different kinds, which
may all be included under these two, clay,
and slate or stone marl ; for what is com-
monly called *shell-marl*, is an animal sub-
stance, and therefore to be classed amongst
F them.

them. The different colours of marl make no real difference as to their properties.

Exp. 20. It is a distinguishing and characteristic property of this body, that, when it is put into water, it falls down into a powder. The clay marl dissolves much quicker than the stone marl. This quality must be owing to the weak adhesion of its particles; so that the small force with which water enters its pores, is capable of separating the particles of the marl. By this property it is sufficiently distinguished from all the earths which we have mentioned; and particularly from clay, which does not so speedily admit the entrance of water.

As marl is so much opened by water, so as to lose its natural cohesion entirely, we see how much it will favour the escape of water from such grounds as have been manured with it. Clay grounds, after they have been marled, become much drier. It is owing, I imagine, to the water getting

ting off so quickly, that marled grounds, as is observed, are less affected by frost, than the same soils which have not got any marl.

Exp. 21. It effervesces with all the different acids, and turns with them into a neutral salt. During the effervescence with the oil of vitriol, a sulphureous steam arose, which is a strong presumption of its containing some oily substance. The clay marl seemed to dissolve faster than the stone marl, and destroyed about a third more of the acids. This quality which marl has of attracting and destroying acids, is one of its distinguishing properties, without which no substance can be called marl. In this quality it is likewise distinguishable from clay.

As farmers are extremely inaccurate in their terms, they often give the name of marl to bodies which do not effervesce with acids. That such substances may and do fructify ground, is indubitable; but they ought not therefore to be called marl.

Surely bodies which do, and bodies which do not effervesce with acids, are very different in their nature, and ought to have different names. As the name of marl, then, is generally, so let it be only applied to the former class. The latter should have such names as will distinguish them from the former. This shews what confusion there is in the terms of agriculture, and how much they stand in need of being defined.

Exp. 22. Another quality belonging to marl, by which it is distinguished from clay, is, that it cannot be converted to brick. It is indeed very much altered by a strong heat: It loses its antacid quality while it remains unpowdered; and is no longer dissolvable in water, as it was before; but still it is very different from a half-vitrified substance; and I much question, whether or not it can, without any addition, be turned into glass. This is a strong proof, that it contains no salts, acid, alkaline,

alkaline, or neutral ; for these are capable of vitrifying lime when added to it.

Exp. 23. I could not get any salt from these marls, either by simple lixiviation, or distillation, though I urged them with the strongest fire. The fire separated nothing but a little water, which appeared to be gently alkalescent ; owing perhaps to some of the finer marly particles which were carried up by the water. No oil appeared in the distillation. When the powder of marl was thrown on fused nitre, it sparkled a very little. This, and the sulphureous smell arising when it was dissolved by the oil of vitriol, would incline me to think, that it has a small proportion of an oleaginous matter in its composition.

BUT though perhaps it contains none, yet it strongly attracts all oils. This is a quality which the chymists know belongs to all absorbent earths ; these they make use of to separate oils from other bodies. Hence it will attract and fix the oils which

it meets with in the ground, which fall with the snow and rain; and even those which, floating in the air, touch its surface.

To enquire a little further into its nature, and separate its antacid parts from the others, that we might discover both; *Exp. 24.* I took half an ounce of stone marl in powder, and saturated it with spirit of nitre, by adding the acid in small quantities for five days; the saline liquor was filtered through brown paper. There remained in the paper three drachms of a bluish adhesive earth, which, on trial, appeared to be a fine clay. To recover the other part from the saline liquor, I added *ol. tart. p. del.* till no more lactescency appeared; a white substance fell to the bottom, and was separated from the liquor by filtration. This powder being washed with water, that all the salts might be separated from it, and calcined in a strong kitchen-fire for five hours, gave me a quick-lime, which afforded good lime-water.

FROM

Se&t. III. *Agriculture and Vegetation.* 67

FROM the same quantity of clay marl, treated the same way, I got three drachms and twenty-eight grains of clay, and thirty-two grains of a calcarious earth.

FROM the same quantity of clay marl, faturated with vinegar, and treated the same way, I got two drachms and fifty-nine grains of clay; and the remainder was a calcarious earth, which, being burnt, afforded good lime-water.

THE same quantity of a different clay marl, treated the same way, afforded two drachms and fifty-four grains of clay, and one drachm six grains of a calcarious earth.

THE same quantity of stone marl, treated the same way, afforded just the same proportion of clay and calcarious earth.

MARL, then, is a body composed of lime and clay in different proportions, according to the different kinds of marl, and generally

nerally about one fourth of lime and three-fourths of clay.

FROM this experiment we may easily account why marl falls in water, as lime strongly attracts water; and why it loses this property when burnt, as clay becomes more tenacious by fire; why it cannot be converted to brick, as the lime hinders that close adhesion of the particles of clay which is necessary to constitute brick; why it will not vitrify, as lime is an enemy to all vitrification; and why it shews a small portion of oleaginous matter, as clay contains some oil. By mixing quick or rather effete lime with clay, or a clay soil, we imitate, in some measure, this production of nature, but fall vastly short of her in the equality of the mixture, and perhaps too in the subtilty of the particles.

THERE is a body very similar to marl in its appearance, but very different from it in its effects, and often found in the same bed with the best marl. It is of a darkish

darkish lead colour. Instead of fertilizing ground, it renders the best soils incapable of bearing any kind of vegetables for many years. I have seen the spots on which it was laid entirely barren three years after. I have heard of its effects continuing in other places for a much longer time; nor is it certainly known when its bad effects will end. A body so very destructive to agriculture, deserves to be well characterised, in order to be shunned; and well examined, that we may know whence proceeds this noxious quality, and how to cure it when it has taken place.

THOSE who have been much used to marl, have already discovered a difference betwixt it and this body. The former, they observe, takes a smooth polish from the instruments with which it is wrought, but the latter does not. As this quality alone is scarcely sufficient to distinguish these two bodies from one another, let us apply to experiment for more.

Exp.

Exp. 25. If a piece of it is taken up which has not been much exposed to the influence of the air, it differs very much in taste from marl. Instead of the smooth unctuous taste of the latter, it is acid, and remarkably astringent.

It agrees with marl in falling down into a powder in water; but then it differs remarkably from it in raising no effervescence with acids, nor in the least destroying their acidity.

It turns the syrup of violets red; which shows, that it contains an acid; whereas marl, like all absorbent earths, gives it a green colour.

THESE qualities are sufficient to teach the farmer how to distinguish this poisonous body from marl, and how to shun it. Let us now try if we can discover on what principles this poisonous quality depends; for if we can investigate its nature, we may perhaps find out a cure for it. Besides, all
pursuits

purfuits of this kind lead us directly to the true fyftem of vegetation. The vegetable is like the animal body, whose nature is afcertained as well by what does it harm, as by what does it good.

FROM my experiments in the fection on till, I imagined that its poifonous quality might depend on its containing fome falt of fteel. I, therefore, directed moft of my trials on this body with that view.

Exp. 26. Some of it was infufed in warm water. The water had a greenifh colour, tafted gently acid, and very astringent. It gave the fyrup of violets a pale red colour. *Ol. tart. p. d.* dropt into it made no fenfible effervescence, but feparated fome air bubbles, difcoloured it, and precipitated a pale red powder from it. Some of this powder was put into a cruible, and kept in the fire for half an hour. I could recover but little of it again, and that not quite free from the fubftance of the cruible; yet the magnet attracted fome of its particles, and fhewed

shewed that it contained iron. The liquor evaporated gave me a *tartarus vitriolatus*.

THE pure infusion did not alter its colour much on an admixture of galls. But this was no proof that the liquor did not contain salt of steel; for an acid destroys this effect of the galls; and the liquor, as we have already found, contained an acid. To destroy the acid, I poured in *ol. tart. p. d.* into the mixture of the infusion, and galls; it took immediately a brownish colour, and afforded a plentiful precipitation, which, in twenty-four hours, had taken a purple colour.

I boiled a quantity of the earth for half an hour in water strained and evaporated it. A white saline substance remained in the proportion of 6 grains to each ounce, which tasted exactly like salt of steel. This salt dissolved in water, turned syrup of violets green, as does salt of steel; and took a deep black colour with galls: Sufficient proofs of its being salt of steel. Nor
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can its white colour be any objection ; for salt of steel reduced by trituration, evaporation, &c. to a powder, is white ; and the salt which I procured, was a powder.

It appears, then, beyond all doubt, that this substance consists of an earthy body like clay, about an eightieth part of salt of steel, and a small proportion of the vitriolic acid. From other experiments which I have made, the bad effects do not seem to arise from the vitriolic acid ; especially as the acid here appears to be very volatile. But we have already discovered the pernicious quality of salt of steel. Nor is it any wonder, that it should exert itself so powerfully here, considering the quantity of this body laid on ground instead of marl, and the great quantity of this salt in it. The soil must be perfectly saturated with it.

BUT how shall we correct the poisonous quality, if, by mistake, this or such like bodies should be used ? For coal produces

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the same effects from the same cause. There seems to be no other method but that of decomposing the salt ; so that the steely part may be no longer dissolvable in water. The air, by volatilizing the acid, and leaving the chalybeate particles behind, has that effect, by gentle degrees, on salt of steel, when it is dissolved in water. But, in the present case, the acid would not reach the salt, unless the soil were frequently turned over ; and even then much of the salt would be defended by the oleaginous particles of the soil. Marl appears to me to be the proper cure ; for that absorbent earth, having a stronger affinity to the acid of vitriol, than what the iron has, will unite itself with the acid, separate the chalybeate particles, render them insoluble in water, and consequently unfit to enter the vessels of plants. A considerable share of the good effects of marl in all grounds, may, perhaps, be owing to this special effect, *viz.* the destruction of a body, which, in proportion to its quantity, destroys all vegetation.

THERE

THERE is another fossil body very similar to marl in its appearance, and some of its qualities, and may be mistaken for it. It is called by some writers soap-rock, from its similitude to soap, and its being often found in rocks; though I have known it lying on the surface in great quantity. As none has yet analyzed it, we shall undertake that task.

Exp. 27. It is sometimes of a bluish, sometimes of a reddish colour; and when moist, feels exactly like hard soap betwixt the fingers.

It falls like marl when put in water; if it is well mixed with the water, it separates into different parts from their different specific gravity; at the bottom there is a layer of large grey particles; above that are some darker; next those of a dark brown colour; and the uppermost is a light white powder; a great deal of which was suspended in the water for 20 hours.

It effervesces with none of the acids. In this it differs from marl.

Exp. 28. Some of it was lixiviated in water; which being evaporated, gave a very little sea salt.

SOME of it was calcined for 4 hours in a strong kitchen fire. The bluish remained of the same colour; but the red turned lighter in its colour. The first contained a few particles, which were attracted by the magnet; the last almost none. It fell as soon as the unburnt in water, and with the same appearances.

I distilled 4 ounces of it in a strong heat for 8 hours, and it gave me only one ounce of pure water.

It did not detonate with nitre in fusion, but some few sparks appeared, which shews that it contains oil.

THIS

THIS oil I extracted, by boiling 4 ounces of it with 2 ounces of potashes for many hours; to this decoction I added spirit of nitre, and got a precipitation of a red heavy oil, which detonated with nitre in fusion.

I took 4 ounces of it, and washed off the light earthy parts by mixing water often with it; in this way I got 10 drachms of a whitish powder, which appeared to be clay. The remainder was composed of two parts, a fine grey powder, which appeared to be sand; and some large particles, white and green. These did not effervesce with acids, nor yielded a tincture of spirit of wine; but felt soft and unctuous in the mouth, and when boiled with soap-ashes, and spirit of nitre added to the lixive, afforded a heavy oil. This shews them to be of an oily nature.

SOAP-ROCK appears from these experiments to contain near a third of clay, a

much greater proportion of sand, and a body of an oily heavy nature.

THAT I might go a little further, and discover its effects in vegetation, and with what soils it would agree best, the following experiment was tried though late in the year.

Exp. 29. A pot was filled with the poorest earth that I could find ; this I shall call No. 1. No. 2. same earth with a third of soap-rock. No. 3. very strong clay with a third of sand. No. 4. the same clay with a third of soap-rock. No. 5. soap-rock alone. In these pots I sowed barley.

THE plants seemed to grow best at first in No. 2 ; but afterwards No. 4. produced the most. In No. 5. the plants were longer of appearing, and seemed more sickly than the others.

S E C T.

S E C T. IV.

Of unburnt calcarious bodies, and quick-lime.

CHALK is reckoned, by the generality of writers, a good manure for all wet clay grounds; for it makes the earth loose and hollow; keeps it dry; and, as the farmers express it, sweetens the soil. The soft unctuous kind is thought the best. Farmers think that it exhausts the soil very much; and therefore they generally advise dung to be laid on along with it. Lime-stone gravel is much used in Ireland as a manure.

THESE calcarious bodies are not dissolvable in any way but by acids. With these a great effervescence happens, a solution of the calcarious body is made, and a neutral salt is formed from that conjunction. This neutral salt is always soluble in water, unless where the acid of vitriol is used.

THESE

THESE calcarious stones, when burnt in a strong fire, turn to quick-lime, a body much used in farming. It attracts acids much more than it did before, and is now in a small degree soluble in water, without their assistance. It is not, however, on these soluble parts that its fructifying power depends; because it has no sensible effect, except in killing vermin the first year, when these parts are most soluble in water. Lime is probably effete, and no longer soluble, when it begins to act on the ground, and assist vegetation. The lime of old houses, which is quite effete, is reckoned better than fresh quick-lime.

THERE is a very great attraction betwixt quick-lime and all oily bodies; it unites intimately with expressed oils. With this intention it is used in the manufacture of soap, to help the junction of the alkaline salts and oils. It must, therefore, attract the oils powerfully from the air and earth, dissolve them, and render them miscible with water: It must, from this reason, soon exhaust

haust the foil of all its oleaginous particles, if the farmer does not take care to supply them by dung or animal substances. Farmers have by experience discovered it to be a great impoverisher of lands, but they did not know how it acted. Its operation is, to exhaust the earth of its oils. Lime laid on ground wore out by continual crops, rather hurts it than improves it; because it does not meet with oil or oleaginous bodies to act upon, and blunt it. The proper cure for this is, to mix dung with the lime, so that it may have something to act on.

LIME is a great dissolver of all bodies, both vegetable and animal, but particularly the latter. We know how soon it dissolves hair and woollen rags into a pulpy substance. This effect is so strong, that, in the common method of speaking, it is said to burn them. In this way it certainly operates in the earth, by dissolving all animal and dry vegetable substances, and converting them to the nourishment of vegetables,

tables, at least sooner than otherwise they would be.

LIME powerfully resists putrefaction, as is discovered by many experiments. It does not appear, therefore, very judicious to mix quick-lime with dunghills, which are not yet sufficiently putrefied, as it must stop that process. When once that process is finished, many good effects may arise from their junction, and particularly that of hindering the oils to be volatilised, and of fixing them.

It is observed of lime, that it is continually falling downwards, so that, in a few years, the greatest part of it is to be found lying together as deep as the plough goes. This is owing to its great specific gravity.

It is likewise observed by farmers, that lime has a better effect on light soils than on stiff, for the first three years, but, after that time, its operation turns much weaker. Light soils are most pervious to the air;
and

and as the good effects of all manures depend on the influence of the air, that influence must be stronger in open soils than in those which are more compact; but as that soil has the loosest texture, the lime falls quickly through it.

BESIDES, by mixing itself with the oleaginous particles of the soil, and converting them to the nourishment of plants, lime becomes in this sense a provocative to the soil. In promoting the work of vegetation, it will soon exhaust all the oils of the light soils, which contain them but in small quantity, and when they are all extraneous, for sand can afford none. But a clay soil, containing in itself a considerable quantity of oil, and that not so easily soluble, is not soon exhausted. An addition of an animal or putrefied vegetable substance to these light soils, would remedy this defect.

S E C T. V.

Of vegetables in an entire and in a corrupted state, and of dunghills.

WE come next to treat of those manures which are drawn from the vegetable kingdom. All vegetables, unless some noxious ones, nourish plants. Malt-dust is reckoned a good manure. Bark of trees, and saw-dust, are recommended by some writers. We learn from *Columella* that the ancients laid the lees of their olive oil on the ground, and found it of great benefit. And, indeed, it is not to be wondered at, that the juices of vegetables already concocted, should prove a nourishment to other vegetables. But it requires much time, before these can be reduced to so small parts, and so dissolved, as to be capable of entering the minute vessels of plants. This is most expeditiously and most effectually performed by the means of corruption.

tion. Hence we may see the reason, why the bun or woody part of flax has no good effect on ground, as the juices are already extracted, by the previous putrefaction which the flax has undergone in the process of steeping, and little now remains but mere earth.

THE different species of sea-weed, especially the kelp, are found very serviceable to land. These weeds are of a soft pulpy texture, and easily dissolve. Besides, there are no plants which contain so much salt, and so much oil, in proportion to their earthy parts. The salts are in such quantity, that the kelp, though very dry, will not burn; as all salts, nitre excepted, are enemies to fire. The oils are discovered to be in great plenty, because this plant, notwithstanding these salts, putrefies very soon. The ashes of this plant * consist of about equal parts of alkaline salt, sea-salt, an oily substance, and an earth.

* Vid. Experiments on bleaching, part 3. sect. 6.

DUNG probably was the manure first used by farmers, as all vegetables spontaneously turn to it, and as accident must soon have discovered its good effects. It is the manure at present most used. The manner in which it is made, is, therefore, a speculation worthy of our attention, and may lead to some useful hints in the management of dunghills.

PUTREFACTION is defined by chymists to be an intestine motion of a body, whereby the union, texture, colour, smell, and taste are destroyed.

THERE is no change so common in nature, as that of bodies from an entire to a corrupted state. All vegetables, whether acid, acescent, alkalescent, austere, aromatic, insipid, cold or hot, are liable to corruption, and generally end in it. The alkalescent, such as onions, celery, &c. run immediately into corruption, without undergoing the other two fermentations; but the acescent can be made first to ferment
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into wine, and generally of themselves undergo the acetous fermentation, before they fall into the putrid. Animals are continually in the very confines of putrefaction; and when death stops the circulation and admission of fresh juices, they fall immediately into it. Animals, and alkalescent plants, as they want that acid which abounds in the acescent plants, have a greater tendency to putrefaction, which every one knows is greatly retarded by acids. Next to the excrements, which are already in a state of high putrefaction, the blood is the most putrescible fluid in the whole body; then the urine; and afterwards the solids.

THERE are three circumstances necessary to the process of putrefaction, *viz.* moisture, heat, and the admission of the external air. Moisture is necessary to soften the fibres of plants, that they may be capable of the intestine motion; for we see that dry straw will not corrupt. Heat is likewise necessary, in order to excite and promote that in-

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ternal motion of the particles which constitutes putrefaction. As cold checks this motion, it is a great enemy to all corruption. The admission of the external air is likewise necessary, as no intestine motion can begin without its assistance. Hence bodies preserved from the immediate contact of the external air, by being put in an exhausted receiver, or covered over with grease, are kept from corruption.

BESIDES driness, cold, and want of air, there are many other things which resist corruption. But there are no species of bodies which are so much in opposition to it as salts in general, whether alkaline, neutral, or acid, but particularly the last.

THE particular seat or subject of corruption, seems to be in the mucilaginous or oily particles; for the more of these fat oily particles a body has, it corrupts, *ceteris paribus*, the easier. Thus water, replete with the mucilaginous particles of an oozy fat

fat soil, corrupts sooner than water taken from a gravelly soil.

THE natural progress of putrefaction in vegetables is in this way. They begin first to heat towards the centre; and emit a sharp acid smell, which is owing to the acetous fermentation. As the heat advances, this smell goes off, and is succeeded by a very foetid one. Their colour, if it was light before, now turns dark; and the more the putrefaction advances, the darker is always the colour. They lose their peculiar distinguishing taste, and gain a nauseous cadaverous one. Their fibres, which had a certain degree of firmness, lose that very soon; there is no more cohesion betwixt the minute particles of which they were composed, and they fall into a putrid pulp. These are the general circumstances which attend putrefaction.

If vegetables are examined chymically after putrefaction, they afford principles very different from what they did before it.

Their salts, which were before fixed, are now become volatile, and their oils are much more volatile and foetid than what they were. The foetid smell of putrefied bodies is owing to these volatile foetid oils flying continually off. This greater volatility in the salts and oils arises from their being more attenuated than what they were.

How nature brings about these great changes, is difficult to say. The most plausible and general theory is, that the minute particles of air, of which there is great plenty inclosed in all bodies, extricating themselves from the fibres of the vegetable, which is now softened by moisture, and being agitated by the heat and continual alterations in the pressure of the atmosphere, raise an intestine motion in the body. This intestine motion, causing a continual friction betwixt the salts, oils, water, and earthy particles of the plant, must comminute them, and raise a great degree of heat. The oily particles undergo

a change from this heat, and acquire a fœtor; and, being joined by the air coming from the putrefied mafs, become more volatile, and affect the fenfe of fmelling. The intestine motion, it is eafy to perceive, muft take away all cohesion in the fibres and particles; and fo they fall into a pulpy fubftance. The oils and falts having a natural affinity, will unite; and fo the falts, by the natural volatility of the oil, will become volatile themfelves, from being fixed before.

THIS is a very plaufible theory, though, I muft own, liable to many objections. The heat and weight of the atmofphere, muft reach bodies preferved by the means of oil, as well as if they were not rubbed with it. We do not find thofe vegetables which are moft apt to putrefy, contain more air, than thofe which are lefs liable to putrefaction. The fixed air of vegetables is not acted upon by heat; nor does there appear any caufe why it fhould get free. It is difficult to arrive at any degree of certainty

tainty in these abstruse speculations. To me the first mover seems to be that elementary fire which is inclosed in all bodies, set in motion by the external heat of the atmosphere. Hence the particles are made to recede ; and the fixed air uniting, becomes elastic, and bursts the vessels of the vegetable body.

THE design and end of this process is more apparent, than the means which the Author of nature takes to accomplish these. Were vegetables to be destroyed only by external force, by far the greatest part of them would remain untouched ; and so be an useless burthen on nature. Were they to be destroyed by an internal fermentation, as at present, without having their parts volatilised, the particles to which they must be reduced, would be continually washed off from the soil, carried into the sea, and so be of little use towards the nourishment of other plants.

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THE only proper and wise scheme is followed. The oils and salts, from being fixed, are volatilized, carried up into the air, and descend again to fructify the earth, which was lately robbed of them. Corruption, then, is the parent of vegetation; and could be so in no other way than in the present. Though of seeming disadvantage in nature, as shewing it on the decay; though highly disagreeable to the external senses, and often dangerous to health; yet is putrefaction of more use than any of the other two fermentations, as it provides for our future nourishment, and carries on that beautiful circle, which nature is commanded, by her Author and constant Supporter, to move in.

PUTREFIED substances are all of an alkaline nature. The alkaline salt is often indeed inviscated by the oily parts, so that it can scarcely effervesce with acids. This has led some to assert, that putrefied substances were not alkaline; an assertion opposite to experiment. We know with what

a gentle heat the volatile salts of putrefied bodies rise ; a heat incapable to form those salts, if they did not pre-exist ; but capable of raising them when once formed. As pigeons dung is the strongest of all dungs, for vegetable and animal substances are the same when putrefied, the alkaline salts are most observable in it. I have seen the surface of that dung covered with a white salt, which smelt as strong as the volatile salt of hartshorn. Every one is sensible of his eyes watering, when he goes into a pigeon-house ; owing to the pungent volatile salts in the air. Substances highly putrefied effervesce with acids. *Reaumur* speaking of the leaves of the vine, which he had set by to putrefy : *Quand elles ont été pourries jusque a ce point ou elles perdent leur nommes pour prendre celui de terreau, elles ont fermenté vivement et subitement avec les acides, que je verses dessus. Au lieu que l'esprit de nitre versé sur de feuilles seches, ou sur de feuilles simplement commencé a pourrir, n'ici produit aucune fermentation sensible.* This experiment

periment puts the question beyond all doubt.

FARMERS have discovered, by long experience, that the dung of different animals differs very much, as to the quantity to be used, and the ground upon which it ought to be laid. A much smaller quantity of pigeons dung must be employed than of any other; and even that should be laid on cold wet soil. The dung of sheep and hogs seems, by experience, to have the preference to all others. These different effects depend on the different quantities of oil and volatile salts in the dung; and these again on the food of the animal, on the time it stays in the intestine canal, on the nature of the juices mixed with the aliment there, and on the natural heat of the body.

LET us now make some practical observations with regard to the management of dunghills: for this is an affair of considerable

able importance, and in which farmers seem to be very ignorant.

DRY vegetables require a considerable degree of moisture before they can be brought to putrefy. I think dunghills are generally kept too dry, as they are commonly in this country placed on a high situation, and are themselves raised to a considerable height. A hollow situation, which will retain the moisture, is the best. Too much moisture is likewise bad. This may be prevented, by having hollow places, with clay bottoms, at the side of the dunghill, into which the superfluous moisture may be allowed to run, and from whence it may be restored again by pumps to the dunghill at pleasure.

BUT there is yet a worse consequence from such a situation. The juices of the dunghill are dissolvable in water, and are continually washed off by the rains which fall. Hence a great part, nay almost the whole of the vegetable food, is lost. It is

a bad advice, therefore, which the *Journal O'Economique* gives, to place the dunghill on a declivity. A hollow situation, where the bottom is clay, or where it is caufeyed is the properest to carry on the process of corruption.

As the sun and wind exhales the volatile salts and oils, and as too much air rather retards this process, I should think it very reasonable, to place the dunghill in a situation shadowed and surrounded by trees. There is a closeness and moisture in this situation which will very much favour corruption.

I see that practical farmers advise, that the dunghill should be covered with earth, to hinder the volatile particles from flying off. But how can this be done, when there are fresh additions made to the dunghill every day? It would indeed putrefy sooner; but then it must lose the influence of the air, by which only it becomes fit nourishment for vegetables. The effects

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of the air on the dunghill must be considerable, as it is so loose and pervious a body. I am more inclined to agree with them in another observation, that the north and east winds should have free access, especially in winter, to the dunghill. We shall afterwards see, that these winds are found, by experience, to be more impregnated with the aerial nourishment than the others, and particularly at that time.

As the process of corruption, in the common way, goes on very slowly ; and as great part of the dung which is carried out from the dunghill is not half putrefied, and consequently not sufficiently prepared for vegetables ; it would be of use to quicken that process, if we knew of any easy method to do it. There are ferments for the putrefactive fermentation, as well as for the vinous. Hence *Stahl* : *Corpus in putredine existens, alio a putredine libero facillime corruptionem conciliat ; quia illud ipsum, quod in motu intestino jam positum est, alterum quiescens, ad talem motum tamen proclive, in eundem*

eundem motum intestinum facile abripere potest.

ANIMAL substances already putrefied, such as stale urine, human dung, the carcasses of animals, &c. are the proper putrid ferments. If the urine of horses and stalled cattle, is carried into proper reservoirs, and there allowed to turn stale, it will, if thrown on the dunghill, very much quicken the fermentation.

PUTRIFIED bodies are of a very volatile nature ; insomuch that if exposed to a dry hot air, they continually diminish in bulk, until all the volatile parts being carried off, the remainder is found to be an earth mostly of the absorbent kind. This shows, that dunghills should not be kept too long after they are sufficiently putrefied ; and that dung should not be exposed on the surface of the ground in hot weather, as often happens ; but immediatly ploughed in, if carried out at that time. It is asserted by some farmers of observation,

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that dung, when exposed for five or six weeks on the surface fructifies ground more, than when it is directly ploughed in, and mixed with the soil. If this observation is found to be true, the winter and spring will be the properest seasons for exposing it. A superficial ploughing after the dung is spread, would seem to bid fairest for attaining the advantages and shunning the disadvantages of both methods.

THE mud of ponds and ditches comes properly under the class of putrefied bodies, as it consists of earth and the putrefied parts of vegetables.

S E C T. VI.

Of manures which arise from burning vegetables.

ALL vegetables converted into ashes by the action of the fire afford a good nourishment for vegetables, especially for grass; because, as their action is very sudden,

sudden, it is sooner observable on a grass than corn field. Chymistry shows, that these ashes consist of an indissoluble earth, and an alkaline salt; which latter body attracts acids more strongly than any other. Fern ashes contain the most salt of any common vegetable which I know; the sixth part is alkaline salt. They must, therefore, be the properest for this use. At the alum works near *Scarborough*, the farmer pays 2 s. a-cart-load for the refuse of the earth of these ashes, after almost all the salt is extracted out of them. The refuse of the soap manufactures, and of the bleachfield, are rich manures. The ashes of peat, which are most used, afford salts equal only to the thirty-second part of the whole, and are the weakest of all those I know.

HERE we must class the burning of the turf, or surface, which is often done to improve poor soil. Farmers think it acts by dispelling a sour juice which land has contracted from lying long untilld: and they

chiefly prescribe it for that sort of poor ground ; for they all agree, that it hurts rich soil. But I imagine, that the benefit arising from it is owing to the [alkaline salt arising from burning the roots of vegetables ; for farmers injoin us to go no deeper than those roots ; and it is found that the greater the quantity of roots, as happens in land which has been long untilled, the more benefit arises from burning.

THERE is another manure which takes its rise from fire, and properly belongs to this section ; that is, foot. This is found, by chymical experiments, to be a composition of volatile alkaline salt, oil, and a little earth. It is remarked, that the effects of this compost are very sudden, they being observable after the first rains.

S E C T. VII.

Of animal manures.

ALL animal substances enrich ground prodigiously; such as, blood, garbage, urine, &c. because they putrefy easily. As we have treated of dung, we need not speak of these. But there are other animal substances, such as shavings and tips of horns, hair, silk, woollen rags, &c. which do not seem, from their firm texture, to be so capable of putrefaction. All these contain a great quantity of a mucilaginous and gelatinous substance, capable of being dissolved by water, of a saponaceous nature, and consisting, as appears by chymical experiments, of salts and oils intimately mixed, and dissolved in much water. This mucilaginous substance must, then, be fit nourishment for plants.

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THE action of these manures is commonly attributed to their imbibing the dews, and conveying moisture to the ground. But woollen rags rather repel, from their oily nature, than attract moisture; and were they only simply to conduct the moisture into the ground, linen rags would do as well; but they do not. These woollen rags being much used in chalky grounds, which are dry, has given rise to this opinion. What these grounds stand most in need of, is a mucilaginous substance, which these rags are full of.

THE animal shells, such as oyster-shells, periwinkles, cockles, &c. must be included amongst animal substances. These are long of dissolving; but it is observed, that in six or seven years they make the ground so mellow, that it must be allowed to stand a year or two, that it may consolidate again, and the ferment be restrained; else it is not able to support the corn. The reason of this expansion of the earth, will appear from the expansive force of shell-marl. These different shells are a composition

composition of calcarious particles, fit to be converted, by the fire, into quick-lime, and of an animal oil.

WE must here consider a body, called *shell-marl*, which is commonly, though improperly, classed with the marls. It must be ranked amongst the shells, as it is a putrefied animal shell. It is a white light substance, with an odorous smell, appearing to the eye to consist of a number of small shells, and generally found at the depth of a foot or two in those hollow grounds which have been formerly overflowed. An animal inhabiting such a shell I have met with in ponds, though it is very rare. It must have been once a very common creature in this country, and appears to have been destroyed in most counties at once by some general disaster which affected it; the natural deposition of soil from these waters has buried it so deep.

Exp. 30. When water is poured on this body, it sucks it in greedily, and swells
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like a sponge ; becomes very soft, but does not fall down like marl into a powder. It is by means of this quality that all shells, whether they are laid on corrupted, or become so in the soil, make ground so very light and spungy.

I could discover no salt in it, by the different trials which I made. It makes a strong effervescence with acids, and requires six times more of them to saturate it than what any of the marls which I have yet met with do.

It affords on distillation, like all animal substances, a urinous alkaline spirit, and an oil of the heavy kind.

WHEN calcined in the fire, it is converted to quick-lime. By these experiments it does appear plainly to be a putrefied animal shell, easily separable by water, and a strong attracter of acids.

P A R T III.

S E C T I O N I.

The effects of different substances with regard to vegetation.

THOSE manures which I have examined, are such as chance discovered to be useful in vegetation, and practice has continued, because they can be easily and cheaply got. But, for what we know, there may be others, which, though not in such plenty as to be of use to the farmer, may have effects on vegetation, that may be useful to those who inquire into the nature of the vegetable food. The more they know of the effects of different bodies on plants, the greater chance they have to discover the nourishment of plants; at least this is the only road. I made the following experiment with this design.

Exp.

Exp. 31. May 2. 1755, I took some virgin earth from the side of a steep bank, where neither dung nor plough had ever been; filled some pots with it; mixed with the earth the following materials; and set them in the ground. Each pot contained about 6 lb. of earth. In each pot I planted five grains of the same barley; and that I might be sure that each grain was proper for seed, I took none but what fell to the bottom of water. No. 1. contained plain virgin earth, that I might have a standard for the rest. No. 2. was always watered with hard water. No. 3. had 1 oz. of salt-petre, and 2 oz. of oil of olives, mixed with the earth. No. 4. contained 1 oz. of salt-petre. No. 5. contained half an oz. of vitriolated tartar. No. 6. contained 1 oz. of flour of brimstone. No. 7. contained half an oz. of spirit of hartshorn. No. 8. contained 2 oz. of oil of olives. No. 9. contained spirit of nitre, diluted with water, half an oz. No. 10. contained of sea-salt 1 oz. No. 11. contained plain earth, and the grains steeped
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for 16 hours in a strong lye of hens dung and saltpetre.

May 9. when I looked at them again, No. 1. and 2. had each one plant, just appearing above ground. No. 6. had two taller than the former. No. 8. had all the five up, one of which was three-fourths of an inch tall.

May 11. No. 1. has all five up, and about half an inch high. No. 2. has two, and as high. No. 3. 4. and 5. have one each, just appearing. No. 6. has four three-fourths of an inch tall. No. 7. has one, half an inch tall. No. 8. has five one inch tall. No. 9. has two, just appearing. No. 10. has none. No. 11. has four. Some of the same grain set in the garden-mould just beside the pots, were three-fourths of an inch high.

May 21. five or six days rain, and then fair weather. No. 1. and 2. have five, about four inches tall. No. 3. has four, three
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inches tall. No. 4. has five, about two inches tall. Those in No. 5. are three inches tall. No. 6. has five equal to No. 1. and 2. No. 7. has two, about one inch. No. 8. has six, two and a half inches tall. No. 9. has three, above half an inch tall, and very ill coloured. No. 10. has one, half an inch tall. No. 11. has five, which are the best of all.

June 1. No. 2. the best of all, nine inches high, and of the deepest green. No. 11. contained the next for size and colour, and was but little inferior. No. 6. next in height, but had many withered leaves; No. 3. 4. and 5. about five inches tall, and of much the same colour; No. 7. about an inch tall, with some of the leaves withered; No. 8. high, but somewhat withered; No. 10. has three about an inch long.

June 10. No. 2. still best. No. 6. almost withered. No. 7. entirely withered. No. 9. and 10. contained poor sickly plants.

June

June 18. No. 2. still best, and has nineteen stalks. No. 11. next, and has ten stalks. No. 1. not quite so tall, but has thirteen stalks. No. 3. comes next. No. 6. almost quite gone. No. 7. none. No. 8. and 9. equal. No. 10. least of all.

Aug. 16. No. 1. has seventeen ears of corn. No. 2. has nineteen. No. 3. has thirteen. No. 4. has fifteen. No. 5. has twenty-nine. No. 8. has nine, and those very large. No. 9. has twenty, and those large. No. 10. has stalks about a foot in length, and four or five ears, about one inch long only. No. 11. has eighteen very good ones.

THUS I have related the experiment faithfully and minutely, as becomes every experimenter. The facts should always be related by themselves, distinct from all reasoning; for we may err in the latter, but the former is truth itself. I should have been glad to have repeated these experiments, especially with a poorer soil than what I found, by experiment this to

be. I should have been glad to have had a greater fund of experiments to have reasoned upon, as there is always danger of some mistake in reasoning from a single experiment. But it is to be remembered, that such experiments can be made only once a-year, and there is no time left now to repeat and augment them. As it then stands, I shall draw some conclusions from it.

Corollary 1. Virgin earth, taken up within a foot of the surface, and from a bank which had a north aspect, contains in itself the principles of vegetation in great plenty. Such earth is used as a manure by farmers; and they observe, that virgin soil will fructify earth much richer in appearance than itself.

Cor. 2. Grain appears to grow better, that it has been steeped in dung and saltpetre. It is a fact long ago observed, that grain vegetates stronger, quicker, and is less subject to blight and mildew, if it has been steeped

steeped in liquors which contain salt and oil, such as sea-water, stale urine, &c. This is easily accounted for. It is certainly of great moment, with what the vessels of the seed are at first filled, whether with watery or with rich juices. This is one great reason that makes a dry feed-time so useful ; for if the ground is dry, the juices which the seed imbibes, are rich and nutritious ; whereas in rainy weather, these juices are diluted with too much rain, and the tender plant is weakened. In medicating grains, we fill their vessels with plenty of salts and oils, and give them vigour to send out many roots, upon which the nourishment of plants depends. The way to make a strong man, is to nourish the child with suitable food.

Cor. 3. Hard water appears to afford a strong nourishment for plants. This is very opposite to the common received opinion ; for gardeners never use it, when they can get soft water ; and if they suspect any hardness, endeavour to soften it as much

as they can, by letting it stand exposed for some time to the heat of the sun. In this, however they are mistaken. This exposition may make water harder; but can never soften water which is considerably hard. The hardness of this water which I used, and indeed of all hard waters * which I have met with, was discovered, by experiments, to be owing to the acid of nitre, joined to an absorbent earthy base. The base in this water was a calcarious earth; in most hard waters it is only an absorbent.

Cor. 4. Oil of olives, in the proportion of 1 oz. to 3 lb. of earth, appeared to have very good effects at first; but these afterwards declined. The ears were good, though not many. Was the oil in too great quantity? Was it not sufficiently attenuated by the salts in the earth; and,

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* Vid. Experiments on bleaching, sect. on hard waters.

by that means, did it not block up the mouths of the radical vessels? Had it not sufficient time to incorporate with the earth? These are questions which I cannot resolve.

Cor. 5. It appears, that saltpetre, in the proportion of 1 oz. to 6 lb. of earth, rather retarded than promoted vegetation. This indeed surpris'd me, as I generally believed nitre to be of a very fruitful nature; nay, the very cause of fertility. It does not seem to have been employed in too great quantity neither. Its great reputation for fertility would make one cautious in doubting that effect, without a sufficient number of experiments to support that opinion.

Cor. 6. The vegetative effects of nitre does not seem to have been increased by the addition of twice its quantity of oil of olives. The oil of olives seems to have succeeded better with the addition of the nitre than without it. The salts would
attenuate

attenuate the oil, and help it to enter the vessels of the plant more easily.

Cor. 7. Vitriolated tartar, which is a composition of the acid of vitriol and an alkaline salt, seems to promote vegetation very strongly. A gentleman wanted to destroy some rank grass in his court, and was advised to sprinkle it with the oil of vitriol, as the greatest enemy to vegetation. He did so ; but, to his great surprise, the grass came up much stronger than before.

Cor. 8. Sea-salt, in the proportion of 1 oz. to 6 lb. of earth, seems to be an enemy to vegetation. Most farmers commend it as a good manure, though there are some who doubt of its good effects. Perhaps in a smaller quantity, its effects may be more beneficial ; especially if it contains the bittern, which is a composition of the vitriolic acid and an absorbent base, and a bituminous oil, both of which must be assistants of vegetation. The salt
which

which I used being table-salt, was in a great measure freed from these.

Cor. 9. The acid of nitre seems to have retarded vegetation at first; perhaps from its being not sufficiently united to the absorbent particles of the soil. But at last it seems to have promoted the growth of the plants considerably.

Cor. 10. Spirit of hartshorn, which is a volatile salt diluted with water, seems to have poisoned the young plants.

Cor. 11. Flowers of brimstone, 1 oz. to 6 lb. of earth, appears to have promoted vegetation greatly at first; but in a month's time to have destroyed the plants like a poison. This substance is often sprinkled on turnip-feed before it is sowed; and it is thought by farmers to assist their growth, and to keep the flies from the leaves. Was too great a quantity of it used in this experiment? Plants, therefore, have not only their food, but their poison. *Quær.* Will
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the artificial sulphur, which arises from the combustion of many plants in a particular way, and which is to be found in great plenty in kelp-ashes, in the soap-ashes, and in many of the ashes used in the bleach-field, have the same bad effects as natural sulphur?

AFTER the last experiment was made, there appeared to me a considerable difference betwixt the method by which it was carried on, and the course which nature follows in such operations. I mixed the materials, whose effects on vegetation I wanted to discover, all at once with the earth; but in a natural way, the fructifying principles must be bestowed on it by gentle degrees, and in very small quantities. Earth, indeed, which has lain for some time fallowed, and is therefore well stored with the seeds of vegetation, is much in the same state with the earth of my experiments, though not so much saturated with the nutritive principles, as mine was with the different materials. Besides, the
former

former is constantly receiving fresh supplies. That I might approach nearer to the course of nature, and supply materials according to the growth of the plants, the following experiments were made.

Exp. 32. Six pots were filled with poor, light, virgin earth. Each pot contained 5 lb. and 5 grains of heavy barley. No. 1. had no mixture. No. 2. was watered with 1 dr. of saltpetre dissolved in 3 oz. of water. No. 3. with the same quantity of sea-salt. No. 4. with the same of Epsom salt, which is composed of the acid of vitriol, and the earth, called *magnesia alba*. No. 5. with 2 dr. of the following composition diluted in water. Half an oz. of quick-lime was saturated with weak spirit of nitre, which produces a very caustic liquor. No. 6. with 2 dr. of the former mixture, having half its quantity of oil of olives mixed with it. This composition appeared to me to approach near to the natural vegetable food. All the seeds were sown *June 16. 1756*, except No. 6. which was not till the 19th of
of

of *June*. I planted some of the same seeds in the garden-mould beside the pots.

June 23. No. 1. has one plant, half an inch high. No. 2. has one, an inch tall, and another, just appearing. No. 3. none. No. 4. has four, two of which are one inch tall. No. 5. none. No. 6. has three, one inch tall.

June 27. No. 1. has four, two and an half inches high. No. 2. has four. No. 3. has two, the tallest is an inch high. No. 4. has five, two inches. No. 5. none. No. 6. has four as tall as No. 4. Those in the rich garden soil were three and an half inches tall.

July 4. No. 2. taller and greener than No. 1. No. 4. and 6. equal to No. 1.

July 10. No. 2. best. No. 6. next. No. 4. next. No. 1. and 3. follow. No. 5. has one, three inches high.

July

July 15. No. 1. four of the five plants have yellow withered leaves. No. 2. and 6. deepest coloured and tallest. No. 3. and 4. equal. No. 5. has one weak plant, about six inches high. The weather has been hot for ten days. Added to No. 2. 3. and 4. 1 dr. more of each of their salts, and to No. 5. and 6. the same quantities of the same mixtures.

July 24. has rained five days. No. 2. and 6. about fifteen inches tall, and much better than the rest; the latter rather best. No. 4. next best, and twelve inches tall. No. 3. next, and nine inches. No. 1. next. No. 5. has one, about twelve inches. Those in the garden soil near two feet, and have sent up many more stalks.

August 19. The last fortnight cold rainy weather, with easterly winds. No. 6. is the tallest, of the deepest green colour, and therefore the best. The rest as formerly. Added to each the same quantity of salts and mixtures as before.

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September

September 1. Has been good warm weather. The plants as before.

September 26. No. 1. had ten ears, the largest of which carried twenty grains. No. 2. has eleven, the largest of which had twenty-four grains. No. 3. worse than No. 1. No. 4. has thirteen ears, the largest of which carries twenty grains. No. 5. has but one ear; and that is not so ripe, and has smaller grains than the rest. No. 6. has sixteen ears, many of which carry twenty-four grains, and those larger than any of the rest. It has one double ear, which has forty grains. Many of the ears in the garden soil have thirty-two grains.

LET us now draw some corollaries from this experiment.

Cor. 1. Sea-salt added in small quantities, and by gentle degrees, to a poor soil, seems again to be rather hurtful than beneficial to it. What effect it would have on

on a soil full of oleaginous particles, appears not from this experiment.

Cor. 2. Saltpetre managed the same way, promotes vegetation considerably, and appears to have made the soil capable of producing a fourth more.

Cor. 3. Epsom salt applied the same way, is pretty nearly equal in its nutritive power to saltpetre. The foregoing experiment taught me the good effects of the acid of vitriol saturated with an alkaline salt; the present teaches me, that the same acid saturated with a particular absorbent earth, promotes fertility. Hence I concluded, in part 2. sect. 3. that marl added to the same acid, after the poisonous chalybeate particles were separated from it, would rather be of service than disservice to the soil.

Cor. 4. Quick-lime, saturated with spirit of nitre, added in small quantities, and well diluted with water, appears to have hurt the vegetative power of the soil. Was

it used in too great quantity? or did it not meet with what is as necessary to vegetation as itself, a due proportion of oleaginous particles, which nature always supplies in proportion as she supplies the salts? The latter seems to have been the case, from the following corollary.

Cor. 5. The former liquor, with half its quantity of oil of olives added to it, and shaken well together, appears to have enriched the soil most, and to have nearly doubled its fertility.

Cor. 6. None of our admixtures was able to bring the poor light soil to the same fertility with the rich garden mould. And no wonder. There the salts and oils are highly attenuated, duly proportioned, and well mixed, by length of time; and, consequently, fitted to enter the small vessels of the roots. Besides, that soil, by the mixture of putrescent matter, is in a constant state of fermentation, becomes easily penetrable,

trable, and offers a larger field for the roots of plants to feed on.

As lime never acts on the soil till it becomes effete, I was willing to see its effects when saturated in that state with the acid of nitre ; although experiments seem to show, that the product is much of the same nature. Half an oz. of old lime wall, was therefore saturated with the spirit of nitre.

Exp. 33. July 15. 1756, two pots were filled with the same earth as used in the former experiment, and in the same quantity. Three grains of barley were sown in each pot. No. 1. contained plain earth. No. 2. was watered with 1 dr. of the solution well diluted.

July 25. No. 1. has three plants, one inch in height. No. 2. has one, the same height.

Aug. 19. No. 2. has only one ; but that is of a deeper green than any in No. 1.

Added to No. 2. the same quantity of mixture as before.

Sept. 26. No. 2. of a deeper green, has more after-shoots, and a longer ear than any in No. 1.

Cor. I can hardly say whether the soil was the better or the worse for the mixture: for, on one hand, only one of the seeds took effect; and on the other, that plant was in a more thriving state than any plant in the plain earth. This, however, appears plain, that it had not the bad effects of the spirit of nitre and quick-lime in the former experiment. Was this owing to the lime being quick in the former, and effete in the latter case? or to a smaller quantity of the mixture being used? I rather incline to the latter opinion, as the mixtures appear to be similar by experiment.

THAT I might discover the effects of the same solution on rich garden mould,

Exp.

Exp. 34. *July 14, 1756,* I filled two pots with 5 lb. each of that soil; sowed four grains of barley in each, and watered No. 1. with the same quantity of the same solution used in the foregoing experiment. *July 20.* three plants have appeared in each pot; those in No. 2. a degree taller than those in No. 1. *July 27.* the plants in both pots equal. *Aug. 13.* the plants in No. 1. are rather taller than those in No. 2.: but none of them thrive well; either because they were late sown, or because they were in a corner where two tall hedges met, and therefore wanted air. I removed the pots to a more open place. *Sept. 1.* No. 1. has one taller, and of a deeper green, than No. 2. The plants have grown faster than before. *Sept. 30.* the plants are come to no perfection.

Cor. 1. The plants in the two last experiments did not vegetate near so quickly in the same time, as those of the preceding experiment had done. Has not the spring, from some particular causes which operate
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at that time, a peculiar vegetative power, which the summer possesses not in so great a degree? So it appeared to me, although the summer was cold and rainy, like our springs, and the soil in the latter experiment very rich, and in the former taken from the same place that the earth of the foregoing was.

Cor. 2. Plants seem to stand in need of a constant application of free air to their surfaces. All trees in thickets stretch out their branches either laterally or longitudinally, where they can have most air. Does this air act only on their surface? or does it enter the vessels of the plant? If the latter, is not an *impetus* from the air in motion necessary in order to its entrance, as the mere pressure of the air is always the same in similar altitudes?

Cor. 3. The plants seem neither to have been much better, nor much worse, for the addition of the saline mixture.

Exp.

Exp. 35. May 25, 1758, I sowed some barley in 4 different pots, filled with the same poor earth. No. 1. contains the pure earth. No. 2. the same earth frequently watered with a solution of that particular salt found sticking on the plaistered walls of boghouses, &c. It got altogether 1 dr. of this salt. No. 3. same earth watered in the same way with the same quantity of crude tartar, which was the only essential salt that I could get at the time. No. 4. the same earth treated the same way with the same quantity of soluble tartar, which is the former acid salt neutralized with an alkaline salt.

June 10. All pretty equal. *July 25.* No. 1. has two ears, and the worst of all. No. 2. has seven, all larger. No. 3. has five, very good. No. 4. has three.

August 8. No. 1. has nine. No. 2. has fourteen. No. 3. has nine. No. 4. has fifteen.

Aug.

Aug. 22. No. 4. has the heaviest ears, and strongest straw. No. 2. is next to it. No. 3. is better than No. 1.

Cor. 1. The aerial nitre promotes vegetation very much. This salt we elsewhere prove to be the fossil alkali.

Cor. 2. The essential salt of rhenish wine promoted vegetation a little. The same salt neutralized, had very strong effects on the growth of plants.

THAT I might discover the natural effects of rain-water,

Exp. 36. May 23, 1758, I took two pots filled with poor earth, sowed some barley in each, and placed them near the window of a green house, so that they might get air, but no rain. No. 1. was constantly watered with spring-water. No. 2. with the same quantity of rain-water.

June 10. The plants watered with rain-water, seem the best; but those of both
pots

pots appeared sickly for want of a sufficient quantity of air.

Aug. 2. The rain-water appears still best.
22. I cannot say which is best, as they are both so sickly.

THESE are all the experiments which I have made with regard to the effects of different bodies on vegetation. This field has not been cultivated with that attention which the merit and importance of the subject requires. It is indeed extensive, as it takes in the operations of all bodies which can be either dissolved or attenuated, so as to enter the vessels of plants. But it is only from a number and variety of trials made in it, that we can expect to see a just theory of vegetation arise. I could wish, before I attempt that subject, to be possessed of a greater number, and those oftener repeated, that my conclusions might have been more general and more certain. They were such as appeared to me to result naturally

rally from the experiment. How far they are to claim assent, I have left in every one's power to judge.

S E C T. II.

Of the food of vegetables.

WE now come to treat of that important question, What is the food or nourishment of plants? a question which has been much handled, but not sufficiently ascertained yet. It has even been made a question, Whether each plant has not its peculiar and proper food, which it chuses amongst the rest, from some elective power inherent in its roots?

THOSE who take this side of the question, assert, that the advantage arising from the change of species is a certain proof of this; for, if the same nourishment served all grains, the same grain would thrive in the same ground, as well as another; that although wheat will not succeed in the same ground

ground for two years successively, yet it will bear another grain very well ; and that the different nature and properties of vegetable juices are a strong proof on their side.

THOSE who assert, that all vegetables feed on the same food, support their opinion by the following arguments. The longer ground is kept in tillage, though it bears grains of different species, the worse it becomes : But this would not happen, if plants took different particles from the soil : That all sort of weeds starve corn, by taking part of the same nourishment : That fallowing ground would be an useless practice, since there is such a diversity of species : That it would be in vain for plants to have a taste, since they have no local motion : That change of species succeeds, not because plants take only their own food, but because some loosen, while others bind the ground ; some roots go deep into the ground, while others keep about the surface : That it is true, wheat will not suc-

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ceed in the same ground two years successively, because it requires more food than that ground can afford, although there is sufficient nourishment left for other grains; and there would be no time left to plough the ground, as wheat is sown in the harvest: And, That the difference of vegetable juices depends not on the difference of food, but on the particular structure of the vessels of plants.

THE latter opinion must appear to every one to be nearer the truth than the former: Nearer the truth, I say, because the advocates for it seem to think, that one sort of food serves all vegetables. There I differ from them. We saw, by the experiments in the last section, that the salt of hard water, Epsom salt, and the vitriolated tartar, salts very different from one another, nourished vegetables of the same species; and therefore the food is not of one kind. We know that some trees contain the acid of vitriol, because with their charcoal we can make a sulphur. We know, likewise,
that

that some plants contain a nitrous salt, while others one like sea-salt. Some vegetables require a greater proportion of watery parts, and some a smaller. The food of vegetables, then, is not all of the same kind.

THALES maintained, that all things were made from water.

HELMONT was of this opinion, and supported it by an experiment known to every person. He planted a willow, weighing 5 lb. in a pot filled with dry earth. The earth he watered with rain-water. In five years the willow, not computing the leaves which had fallen off, weighed 164 lb.; but the earth had lost nothing. That elementary water is the food of vegetables, is a conclusion too strong from this experiment. It only shows, that water contains particles which are capable of nourishing plants. We have shown, that snow and rain-water contain earth, oil,

and, as they sweep the air, must contain such salts as are in it too.

SOME modern philosophical chymists, such as Mess. *Eller* and *Euler*, are of opinion, that water is the nourishment of plants. The latter found that onions and some branches grew in distilled water. But the experiment does not convince me, for distilled water, as well as rain-water, contains salts and oils. He owns in the same paper, that the distilled water, exposed to the sun, recovered its salts, oils, and earth. It will, then, recover the same principles when the plants grow in it. It is not necessary here to enter into that nice discussion, whether water receives these principles from the air, which I think most probable, or is converted into them, which is his opinion; it is sufficient for my purpose to show, that these principles enter the vessels of the plants along with the water. As I know no experiment that establishes this opinion, it appears to stand in opposition

fition to all my experiments : For some salts have strong vegetative powers ; but these do not arise from attracting and retaining moisture, as these powers do not appear to be in proportion to that quality.

OTHERS think, that the more terrene particles are those which nourish plants. Of this opinion is the famous *Tull* ; because, says he, earth augments them ; and whatsoever augments them, must be their food. Dung, and other manures, act only by fermenting, and so attenuating the soil ; and are of no more use, than, as a knife, to divide their food. But earth alone could never do, without some more active principles. Had *Tull* been a chymist, he would have known, that mere earth makes but a small part of all plants. Soil may certainly be too loose. To earth already sufficiently attenuated, manures would do no service. Whence the salts and oils of plants ? These are objections which the favourers of his system never can answer.

OTHERS, seeing the necessity of the air to all plants, and observing that plants imbibe a great deal during the night, as Dr *Hales's* experiments sufficiently show, assert, that the soil only gives them support, but the air nourishment. To this the answer is short, That plants thriving better in some soils than in others, and in proportion as these soils are manured, shows the ground to be the principal pasture of plants ; the air being the same in grounds adjoining to one another.

THE author of the *Histoire Physique* deduces all plants from certain similar organised parts, which he supposes flying up and down the air in great plenty, and which attach themselves, in some unknown way, each to its own tribe. If this were the case, dung made of plants of the same species, would succeed best ; which is not so. I shall allow this unphilosophical opinion to fall of itself, as it must naturally do, when unsupported by experiments.

OTHERS

OTHERS attribute vegetation to salts of different kinds. But whence they come, and of what nature they are, we have only their own assertion.

IT is the common fate, in all disputed points, that each attaches himself to one side, without allowing the other any share of truth. I have found by experience, that each side has generally some truth in it; that mankind err by extending that particular truth to a general one; and that the real truth is generally made up of somewhat taken from each opinion. The reasoners on agriculture have failed, because they asserted, that plants were fed either by air, water, earth, or salt. I join, in some measure, with all these; and assert, that plants are nourished by these bodies, united with two others, oil and fire in a fixed state. These six principles joined together, in my opinion, constitute the vegetable nourishment.

THIS

THIS easily appears, when we consider,
1. That several kinds of nourishment, such as leather, hair, horn-shavings, rags, and all vegetables, and vegetable juices, in an intire state, prove proper food for vegetables. 2. That all vegetables and vegetable juices afford those very principles, and no other, by all the chymical experiments which have yet been made on them with or without fire. More arguments could be brought ; but these two I think conclusive.

AIR active and fixed is to be had every where, if we were not at much pains to exclude it. Elementary fire is to be found in all bodies. Earth may be supplied by any soil managed with proper care. Water drops from the clouds. Oil is a natural principle of all earth, descends with the rains and snows, and is communicated to the ground by all the vegetable and animal manures, in a sound or putrid state, as our experiments have shewn. But whence the salt, the most active, and, therefore, most necessary principle of all ? We have not

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as yet discovered any in rich soil, nor in the manures most used, *viz.* lime, marl, shells, chalk, &c. This is an important question ; opens up the action of almost all manures, and of rich soils ; shows wherein the effect of the air consists ; and therefore, deserves a particular discussion.

THE preceding experiments have shown, that all fertile soils, and all manures, except those already converted into a mucilaginous nature, consist of particles, which, in part, or all together, attract acids. Dung, the ashes of vegetables, burnt earth, contain such particles ; lime, marl, animal shells, chalk, &c. are wholly of this nature. These then must attract and retain all acids, when they come within the sphere of their attraction. If the air, to which the soil is continually exposed, contains any acids, these bodies will draw it out, and be converted to a neutral saline substance, enjoying the properties of salt, such as solubility in water, dissolving oils, and rendering them miscible with water. Nothing, then,

then, remains to be proved, in order to the conversion of these manures into a salt, but that the air contains an acid salt.

THIS has been the opinion of the greatest chymists, not from theory alone, but because they discovered, that alkaline salts, when exposed to the air, were converted into neutral ones; and that metals, such as tin, copper, and lead, were corroded, and converted to a salt. Whether there is such a salt, and what its nature, will be best ascertained and illustrated, by considering the manufacture of nitre. This process too will show the operation of the different manures, as these are the very materials used in this manufacture.

THE most common materials out of which nitre is made, and, therefore, called the *matrix* of nitre, are the rubbish and earth of old houses, and especially of dove-cotes, stables, and church-isses; particular fat earths; the ashes of burnt vegetables; putrefied animal or vegetable substances; and

and some particular kinds of stones. These materials are exposed to the air for some months, particularly the winter months; for, during that time, nitre is generated in the greatest plenty. The place where the materials are exposed, should be accessible to the air and winds, but not to the rays of the sun, or to the rains. The air is necessary, as it generates the nitre; but the sun is destructive, as it exhales it. The rains are prejudicial, because they wash it away when made. Drought is as destructive, as that exhales the saline parts after they are formed, and hinders the fermentation, necessary to draw the nitre, and to open the matrix to receive it. It is observed, that the north winds are particularly productive of the salt. In the *Indies*, from which we have most of our nitre, they expose earth of a particular kind, mixed with putrefied vegetables, to the air, and from that extract the nitre. *Tournefort* tells us, in his travels, vol. ii. p. 289. “ In our conversation in the caravanfera of *Erzeron*, we learned from those of the caravan of
“ *Wan*,

“ *Wan*, a *Turkish* town on the frontiers of
“ *Persia*, that they carefully lay up in
“ heaps the dirt of the great roads, which
“ are frequented by caravans of camels.
“ This earth they wash, and every year get
“ out of it about 100 quintals of nitre.”

IN the manufactory of nitre at *Paris*, where there is much made, they expose the rubbish of old houses, mixed with the ashes of burnt vegetables, to the influence of the air for some months, and moisten it often with stale urine ; and from those materials extract their nitre. After all the nitre is got out of them, they are as fit as before to form more ; and are again thrown on the heap. This fact shows, that this salt is not the natural salt of the earth, but formed by its exposition to the air. After these earths have been exposed a sufficient time to the air, they are put into different casks, and water poured over them, to lixiviate or dissolve the salts. The materials must be frequently stirred about in the water, that it may dissolve the salts. After the water is sufficiently

sufficiently impregnated with the salts, they draw it off, and add to it some quick-lime, and the ashes of vegetables or alkaline salts, if it has not already got enough of them ; the former to separate the oil from the salt, the latter to give it a fixed alkaline base instead of an earthy one. They add alkaline salts, as long as their addition makes the liquor take a milky appearance, and yield a precipitation. When no more precipitation happens, then they decant the liquor, and boil it up.

LET us now inquire into the origin of nitre. There are various opinions about this salt ; nor are chymists yet agreed about its birth. Some alledge it is attracted, as we see it, from the air : others, that it is produced from the animals and vegetables, or their juices mixed with the nitrous earth, and putrefying there : others, that it is formed from the vitriolic acid, joining to the phlogiston, or inflammable matter of these substances : and others, that the acid of nitre is a different acid from the former,

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and attracted by these bodies, which are its proper matrix. Let us examine these different opinions.

SALTPETRE is an artificial body, as none of it has ever yet been found in the bowels of the earth. Some, authors, on this account, thought that the nitre was altogether attracted from the air by the materials exposed to it. But this opinion is apparently false, as no nitre can be got from those materials before an alkaline salt is added to them. The acid, indeed, does exist in these materials, as I shall afterwards shew ; but the alkaline base must be given it by art, before any nitre will crystallise. Besides, nitre is not of itself a volatile body ; and, therefore, cannot float in the air. The aerial nitre, which is got sticking to old walls, is a very different substance from the nitre we are just now treating of. It has very different properties, such as effervescing with all acids, and a urinous taste.

LEMERY,

LEMERU, in a paper in the *Mem. de l'Acad. des sciences pour l'ann e 1717*, maintains an opinion peculiar, I believe, to himself, That the nitre which is generated, arises from the animal and vegetable substances which are used to collect it. The arguments which he makes use of to support his opinion, are, indeed, few and weak. I think his chief one is, that he has extracted a nitrous salt from some vegetables. It is true, that some of them do contain, in their natural state, an inflammable salt, which appears to have many of the properties of nitre. This is the case with the *carduus benedictus*, wild cucumber, and *pellitory*. *Boildue*, in 1734, has a paper in the academy of sciences, where he says, that he extracted real nitre from a decoction of *bourache*, especially when he added some quick-lime to it, to fix the oily particles the better, that the salts might crystallise. He says, that a mould which formed itself on this decoction, after it had been kept for some time, burnt like oil and nitre. But all this is no proof, that the

nitre comes from the vegetables used in the making nitre; for all kind of vegetables do equally well, even those which contain a vitriolic salt. Besides, no fixed salt is ever got from putrefied vegetables, or from any animal substance, which *Lemery* seems to have forgot. It is surprising, that a chymist should fall into so great an error. These vegetables and animal substances act, as we shall soon see, in a very different way, by affording an absorbent earth, and volatile alkaline salt, and so increasing the matrix to extract the acid from the air; and by keeping the matrix open to admit the air, by a continual fermentation carried on in the body exposed.

THE third opinion, which almost all chymists follow, is, That the alkaline volatile salts, produced by the fermentation of corrupted bodies, animal or vegetable, and the absorbent terrestrial particles, which are used as the matrix to make nitre, attract from the air, which is plentifully stored with it, the *acidum vagum*, or vitriolic

olic acid ; which joining with the oil of the matrix, stored with it, becomes the acid of nitre. This universal acid, *Homburg* makes the origin of the nitrous and the marine acid : for, added to an inflammable matter, it becomes the nitrous acid ; to an arsenical matter, it becomes the marine acid. The arguments used in favour of this opinion are, 1. That putrefied animal substances are employed in the formation of nitre, and, therefore, the oil must join with the vitriolic acid. But this conclusion will not be allowed as a just one, seeing these putrefied substances may have other uses, as we will show. It will presently appear, that nitre may be got without any oily matter. 2. The spirit of nitre has a reddish colour, which they say is an argument, that it contains an inflammable substance, and it is that substance which gives the colour to all bodies. But we know many bodies which are coloured, although we have never yet been able to shew that they contained an oil ; therefore this may not. 3. The inflammability of

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nitre,

nitre, which it owes to its acid, proves, they say, that it contains an oily principle, which is the only inflammable body that we know. To this opinion the answer is plain, That nitre of itself is not inflammable, unless it meets with an inflammable body. This argument becomes rather an objection against this opinion, as it may be said, that nitre inflames with all bodies which contain an oil; and as it is not inflammable of itself, therefore it does not contain an inflammable substance.

THIS leads me to the last opinion, That the nitrous acid exists in the air, and is attracted from it. This opinion, though scarcely maintained by any chymist, to me appears to be the strongest, though still liable to some objections. The first argument for it is, That alkaline salt and calcareous bodies of themselves, without a mixture of any vegetable or animal matter, will produce nitre; as we find by an experiment of *Stahl*, in which he got nitre by exposing alkaline salts to the air. I have
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got a nitrous salt from the lime taken out of park-walls. The second is, That it is actually found existing in nature. Many mineral waters contain a nitrous salt, as appears by the experiments of *Du Clos*, performed before the academy of sciences at *Paris*. I have discovered that the nitrous acid exists in all hard waters *; and that all pit-well waters are hard, and contain a nitrous acid joined to an absorbent base; which imperfect salt, by the addition of an alkaline salt alone, can be converted into real nitre. Thirdly, by boiling hard water, or exposing it to a great degree of heat, the nitrous acid is really volatilised, and the absorbent earth falls to the bottom. This proves, that the nitrous acid is volatile, and exists in the air. The *spiritus nitri fumans* is continually evaporating in the air. These experiments prove, I think, beyond all doubt, that the nitrous acid exists in the air, distinct from the vitriolic acid. This nitrous acid appears to be the
fructifying

* *Vid.* Experiments on bleaching.

fructifying principle which we formerly discovered in the air.

THIS point being settled, let us now account for the different changes brought about in the making of nitre. All earths are not fit for this purpose; only such as are attracters of acids, or absorbent earths, *viz.* lime, marl, and the other absorbents; or putrified vegetables and animals, which afford an absorbent earth, and likewise a volatile salt. Almost all earths have more or less of absorbent particles in their composition. These absorbent earths catch the nitrous acid, as it passes by them with the air, or fix and collect it as it arises from the inner parts of the earth: For I am not sure but it may be got likewise in that way; at least it does not seem to rise very high from the ground. *Mariot's* experiment is a proof of this. He exposed the matrix of nitre for two years on a house-top, and could get no nitre from it; but got it from the same matrix kept in a cellar.

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THE mixture of urine, and of putrefying vegetable and animal substances, will be of considerable use in carrying on an intestine motion in the mass of earth, keeping it open, and allowing the influence of the air to penetrate deeper into the body. If there was no such putrescent body mixed with it, the mass would cohere too firmly together, and its surface would only act; whereas now the whole body acts. It is in this way that I imagine the animal and vegetable substances chiefly operate, and not by entering into the composition of the nitre, as most chymists assert; because nitre may be made by exposing alkaline salts alone to the air; for alkaline salts attract acids, and are so loose as to stand in need of no fermentation to open their texture. The north wind is particularly proper for the generation of nitre, because that wind must bring more of the nitrous acid along with it. That the cold we feel from that wind, is chiefly owing to a greater quantity of this acid, I think is probable, though not demonstrable. The
winter

winter months are particularly good, as the north wind blows more in that season than in any other, and as there is less heat to exhale the nitre during the operation.

IN this way the matrix of nitre is impregnated with the acid of nitre. Let us now see what this matrix at present contains. We have the analysis of it by *Petit* in the academy of sciences. He took 50 lb. of old plaister, and dissolved it in 72 lb. of water. This gave a pungent bitter reddish liquor, which was in weight to common water as 32 to 31. When the water was boiled into a liquid extract, for it would not harden, it soon attracted the moisture, and turned liquid again. It turned blue paper red; showed no effervescence with *sp. nitr.* or *sp. sal. mar.*; and when mixed with the former, dissolved leaf gold. *Ol. vitr.* made a violent fermentation and precipitation with it. *Ol. tart. p. d.* did not easily mix with it; but when stirred, produced a *coagulum* like butter,

butter, and gave a strong urinous smell. If sublimate was mixed with the *ol. tart.* no urinous smell was felt. This *coagulum* was owing to a separation and precipitation of much earth. Spirit of urine had the same effects; but *sp. sal. ammon.* made with lime, had not. Brown paper dipt in it, burned like a match. These experiments show, that it contains absorbent earth, volatile salt, the acid of nitre, and sea-salt.

HE distilled it for five days, and nothing but phlegm, very much charged with a bitumen, came over. When the utmost force of fire was applied, white clouds appeared in the receiver, which clouds condensed into *aq. reg.* By two other distillations he got *sp. nitr.* When *ol. vitr.* was added to it, there happened a violent ebullition, and *aq. reg.* was distilled from it. By the assistance of quick-lime, a small quantity of *sp. vol. urinæ* was got. It appears again to contain an oily substance, earthy matter, volatile salt in a small quantity, some
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of the marine acid, and a great deal of *sp. nitr.* It is easy to account from whence it has got the inflammable matter and volatile salt, *viz.* from the putrefied vegetable and animal substance mixed with it. The sea-salt comes from the urine of animals poured on the matrix of nitre. But he never could extract real nitre from this nitrous earth. That cannot be done, till it has got the addition of an alkaline salt by itself, or contained in the ashes of vegetables. These are generally added to the nitrous mass before the water is poured on; if not, they must be added afterwards.

THE effect which they produce is, to join with the nitrous acid, whenever a sufficient quantity of water is added for them to act: For alkaline salts attract the acid of nitre more strongly than the earthy base does, and the earth is shaken off. Hence it happens, that in boiling, the liquor deposits much of this earth. There should as much alkaline salt be added, as to saturate

rate the nitrous acid fully, and shake off all the absorbent earth. The alkaline salt cannot join to the marine acid, because that has already got an alkaline base.

IF these absorbent earths attract the acid of nitre from the air, in the manufacture of nitre, surely they will do the same when laid on the earth, and be converted to the same salt, consisting of the nitrous acid and an absorbent base. It is not, therefore, a real nitre, as was thought, which is the cause of vegetation, but an imperfect nitrous salt. This reasoning admits yet of stronger proof, when we consider, that this very salt existing in hard waters, has already, by experiment, appeared to be a great assistant of vegetation; and that an artificial one, of much the same nature composed of lime and spirit of nitre, when joined with a proper quantity of an oily substance, rendered a poor soil remarkably fertile.

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IF this reasoning is just, the effects of different manures on the ground should be visible, in proportion to their strength of attracting acids. This happens really so in fact, and is a strong confirmation of the truth of our reasoning: For ashes have the speediest effects of any manure; because the alkaline salts which they contain attract acids stronger than any body. Soot and dung come next, which are volatile alkalines, whose attraction comes next to the first; then the class of absorbent earths. The same observation is made of the marls: For, according to their rank as attracters of acids, so they operate on ground; first shell, next clay, and last of all stone marl; which will sometimes continue in the ground four or five years before it show any effects. The same turn all these manures keep in losing their effects; for the soonest converted to salt must be the soonest exhausted.

AN objection will naturally occur to every one against this opinion, though supported
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ed by the greatest strength of experiment ; which is, That no such nitrous salt is got from fertile earth. In general, these absorbent particles are in such small proportion, even in the richest soil, and such a small degree of fermentation is carried on in it, that there are only a few of these particles, and these too on the surface, capable of being converted to this salt ; and they are no sooner converted than absorbed by some plant. These considerations shew, that little of this nitrous salt is to be expected from any soil. That it is sometimes got, appears from this passage of Lord Bacon, *Hist. vit. et mort. Certissimum est, quamcunque terram licet puram, neque nitrosi admixtam, ita accumulata et tectam, ut immunis sit a radiis solis, neque emittat aliquod vegetabile, colligere etiam satis copiose nitrum.*

ALMOST every person who has examined the contents of this soil, has denied, however, the existence of this nitrous salt

in it. Let us apply to experiment for a decision of this question.

Exp. 37. To put this question beyond all doubt, I took from a molehill some rich soil in the month of *October*, poured water on it, and filtered that water through brown paper. This liquor, when boiled up, was yellow, and tasted saline. The salt appeared plainly to be nitrous; as brown paper, dipt in this liquor, and dried, burnt like a match. On an addition of *ol. tart. p. d.* the liquor turned milky, and let fall a white powder; which shows the salt to be of the same nature with that of hard water. At first, I could get no salt by crystallisation, as the liquor was very unctuous, and in small quantity. But on treating it in the same manner as the manufacturers do the materials of nitre, *viz.* adding some quick-lime to separate the oil from the salts, and allowing it to stand some days, I got from it a true saltpetre. This experiment shows the saline part of the vegetable food to the eye.

FROM



FROM what has been said, we may learn,

Cor. 1. That as hot weather hurts the formation of nitre, by exhaling it, and as the winter and spring is the time in which it is mostly generated, all dung should be laid out in those seasons.

Cor. 2. As these manures become fertile by the action of the air, the longer they are exposed on the surface of the earth, so much the faster will they be converted to the nitrous salt. Farmers are now convinced of this from experience : But such bodies as contain a nutritive juice already formed, as woollen rags, hair, horn-shavings, leather, saw-dust ; or those which already exist in the form of a neutral salt, such as sea-salt, cannot be benefited by the influence of the air. Experience has likewise confirmed this observation. These are strong proofs of the justness of the preceding reasoning.

Cor. 3. As the north-wind is observed to bring most of the nitrous acid, it would

seem to follow, that banks which have a north aspect should receive most of it. It is observed, that they are, in general, richer than those of a southern aspect. As the former have not so much sun as the latter, they should be less fruitful: But our theory of vegetation affords a sufficient reason for this fact.

Cor. 4. It appears from the manufacture of nitre, that all those absorbent meagre earths used in agriculture, will be rendered more capable of answering their purpose, by an addition of some putrid substance, vegetable or animal, to open their texture, and make them more pervious to the influence of the air. Hence the advantage of mixing animal or putrefied vegetable substances with chalk, marl, lime, or the ashes of vegetables.

Cor. 5. As the process for preparing vegetable food is the same with that for making nitre, farmers should imitate the manufacturers

nufacturers of nitre, and the nearer they approach to the methods found most convenient to increase the product of nitre, the more will they multiply the vegetable aliment. In *France* all old walls and houses belong to the King, and are made use of for the extraction of saltpetre. The King of *Prussia*, by a regulation of consummate policy, has eased his subjects of this burthen, shortened the process, and increased the quantity of saltpetre. He has ordered walls of certain dimensions to be built near every village; they are composed of the earth of granaries, stables, or cellars, mixed with other fat earth. They are built to stand some years, till they are sufficiently impregnated with saltpetre. It is observed by Dr. *Pietsch* in his *Penses sur le generation de nitre*, that the people employed in these works, are yet very ignorant, that they might meet with much fat earth below the surface, very fit for their purpose, and that there should always be a proportion of absorbent or calcarious earth
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in these walls. He says, that there is always least nitre on the south side of the wall. He orders, that all vegetables should be pulled from the wall, as they consume the nitre ; that no cattle should be allowed to come near them, as they are fond of it ; and that they should be covered with straw, to hinder the rains from washing off the nitre : What ought then to hinder our farmers from making such walls of fat earth, dung, especially that of pigeons, straw, which will take a time before it rots, and a small proportion of lime, marl, or shells ? Most of these materials will be found every where. In two years they would become a very rich manure. They would operate instantly ; whereas, it takes two years before many of our manures have a sensible effect on the soil. Although heavy rains wash off the nitre, yet a gentle moisture of the materials is of use, as it is necessary to the attraction of all salts. It has been observed, that the southern side of these walls has less nitre. To remedy

medy these defects, I would ³propose, that the wall should be shadowed on the south by a hedge, which will keep off the rays of the sun, hinder it from turning too dry, and allow the air a free passage. The putrefaction, which goes on in such a situation, will be of great advantage to the process.



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P A R T IV.

S E C T I O N I.

Of opening and pulverizing the soil.

IT is not only the business of the farmer to provide food for plants, but to take care that they are able to reach that food. It is of no use if the roots cannot pierce the ground, to get at it. Hence the necessity of opening and pulverizing the soil. Plants are fed mostly by their roots; nor do they begin to grow, until these roots are so numerous as to nourish both themselves and the stem. The wider these roots are spread, the more nourishment will the plant receive, the stronger will it be, the larger will it grow, and the better will it answer the design of nature.

BUT this is not the only view with which we should favour the growth of the
root.

root. That part seems to be the great cause of fecundity ; for it not only nourishes the plant, but sends up many shoots and plants itself. A small piece of the root of many different plants will breed a plant. Many stalks arise from the roots of all the different grains, long after the grain itself is corrupted. Hence, the more roots the more chance of plants : but the quantity of roots seems to depend, in a great measure, on the openness of the soil.

THE soil may indeed be too loose ; for it must have a certain consistency and cohesion to support plants. The gravelly soil is the worse of being often ploughed. It is observed, that a light soil, when much dunged, produces a worse crop of pease than when not dunged. But too great looseness is a rare fault, and is soon remedied. Too great stiffness of the soil is what the farmer has most frequently to struggle with.

LET

LET us, then, examine the methods by which it is kept loose. These may be divided into natural and artificial.

S E C T. II.

Effects of the atmosphere.

THE alternate vicissitudes of the air, are the chief means that nature makes use of to attain this end. Heat and cold, moisture and drought, contract and dilate it by turns ; and, by these alternate motions, shake the particles asunder. But there are no means so efficacious as frost and thaw. Every one must have observed, how loose the soil is after a frost. Many vegetables are at this time ejected out of the earth altogether.

FROST seems to act in different ways. 1st, By changing into an elastic state much of the fixed air, which must shake and open the ground, to gain an exit. 2^{dly}, By the dilatation of the water, as it freezes

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in the earth, the adhering particles must be separated. 3^{dly}, The particles of water shooting out in the manner of salts, must cut and divide the soil.

Cor. That the ground may receive, in the strongest manner, the good effects of frost, it would appear reasonable, that it should get one ploughing before the frost comes on. One furrow at this time will attenuate it more than two afterwards. Regard must always be had to the climate; for where much rain falls in the winter, this practice would prove pernicious, by exposing the soil to be washed away.

S E C T. III.

Change of species.

THERE are some plants designed by the Author of nature to fix the soil; there are others designed to open it. One great division of plants is into the fibrous and

and carrot rooted. The fibrous-rooted divide directly into small fibres, which run in all directions, but mostly horizontally; the carrot-rooted send one great stem directly down, which has lateral fibres. The former, in which class are reckoned all the white grains, rye-grass, &c. consolidate the ground; while the latter, in which class are reckoned the leguminous plants, carrots, turnips, clover, &c. attenuate and loosen the soil exceedingly. The clover is often ejected altogether out of the ground after a frost.

THIS effect must depend on the nature of the roots. The fibrous roots must bind the soil together like so many threads, while the carrot root descends like a wedge, and by its mere mechanical force cuts the earth; perhaps the latter may operate, likewise, by separating more moisture from its root to keep the earth loose. Some plants appear to have this quality. A sprig of^d mint, which has some roots in water, and some in earth, will, according

to *Tull's* experiment, moisten the earth from its roots. The liguminous plants, by covering the soil, keep it moist, hinder the sun to consolidate it, and destroy the weeds which help so much to bind it. Hence the reason why a change of species meliorates the soil so much. When the ground is often sowed with white grain, it turns stiff. A crop of pease, beans, or clover, pulverizes it again.

FARMERS have discovered, by experience, that all the fibrous-rooted plants impoverish the ground, and do not thrive when they succeed one another ; while the carrot-rooted enrich the soil, and may follow one another with success. The latter, by opening the ground, make the influence of the air on it reach deeper, and consequently help to produce more of the vegetable food ; while the former, by consolidating the ground, shut out in a great measure, the influence of the air, and make the ground less fertile.

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It is remarked, that not only a change of species, but also a change of grain, is necessary : for the same grain sown in the same ground is observed to degenerate. This depends on another cause. It seldom happens, I believe, that the vegetable food is of a due mixture and consistency. As soils are generally either too wet or too dry, too light or too stiff ; so must the vegetable food be either too thin and watery, or too thick and gluy. The vegetable must at last be hurt from a constant succession of one sort of food, and can only be recovered by a soil possessed of opposite qualities.

S E C T. IV.

Of ploughing.

PLOUGHING is the artificial method of pulverizing most known and most practised. It acts in two ways ; by an immediate mechanical division and trituration of the soil, and by a more frequent and extensive exposition of it to the influence

and vicissitudes of the atmosphere. I believe the latter operation is the principal one; for so gross an instrument would seem very unfit to prepare the earth to enter the capillary vessels of plants. Its effects, however, are very remarkable. They are beautifully and strongly illustrated by the story related by *Pliny* of *Caius Furius Cresinus*. That farmer, having better crops than his neighbours, fell under the suspicion of witchcraft, was accused before the people, and saw himself ready to be condemned to death. When the tribes were going to vote, he at once produced his rustic instruments, of a greater size than common, larger oxen, and heavier ploughs; and added these remarkable words: *Veneficia mea, Querites, hæc sunt; nec possum vobis ostendere, aut in forum adducere, lucubrationes meas, vigilias, et sudores*. He was unanimously absolved.

THE good effects of ploughing depend entirely on the driness of the ground: for if it is wet, the ground is consolidated instead

stead of being opened ; and remains in that useless state till the next winter's frost loosens it again. None but dry bodies can be reduced to a powder.

THE farmer must open the ground as deep as the roots of his corn penetrate, that they may find an easy passage : and yet he must take care not to go below the soil in ploughing, else he will bury what has been benefited by the air, and expose to the air what perhaps cannot. Hence the plough must be proportioned to the depth of good soil.

It seems strange, that there is not a more certain way of fixing the depth of the plough, and preserving it in that precise situation which the soil requires, than the attention of the ploughman. That must be often suspended by external objects and fatigue ; and then the cattle and soil suffer. Does not the wheel-plough remove this objection ?

THE stiffer the soil, the oftner should it be ploughed. Clay cannot be ploughed too often ; lighter soils perhaps may. It is allowed by many farmers, that the gravelly soil may be hurt by too frequent ploughing.

As this operation depends on the principles of mechanics, and not on those of chymistry, I shall leave it almost untouched to the consideration of some other person. It is a subject worthy of attention ; and although well enough understood, perhaps, for common practice, yet has it not been reduced to that mathematical exactness which all mechanical agents are capable of. I wish that some practical farmer, skilled in mechanics, would lay down the principles on which ploughs ought to be constructed, and ploughing conducted. He would merit much from the community.

S E C T.

S E C T V.

Of composts.

THERE is another method which art uses to keep the soil loose ; and that is, by the admixture of putrid and fermenting bodies. We have seen that these bodies have a strong intestine motion before they are laid on the ground : they continue that afterwards, though in a smaller degree. The fat soil of church-yards swells so much when exposed to the air, by its fermentative power, that it will not go altogether into the same hole out of which it was dug. Clay, which has so few putrescent particles, is the most adhesive soil of any. We have seen already how much shells, when they begin to putrefy, open the soil.

BUT there are other composts, though not of the putrescible sort, which have this attenuating power in a strong degree. In this class are all the marls, but especially the

the softest, such as the clay marl. We have found how readily they lose all adhesion in water, and fall down into a powder. The same power they communicate to other earth, even to the most adhesive. The following experiment is a proof of this.

Exp. 38. Take equal parts of marl and clay, mix them well together, and dry them ; when this compounded substance is put into water, it falls by degrees to the bottom of the glass in the shape of a powder, while a ball of pure clay remains quite undissolved in water. This shows the strong attenuating power which marl has, and which no other body can come up to. It is observed, that all clay grounds, after they are marled, dry fourteen days sooner than what they did before. This is owing to the soil being more loose, by which means the water pervades it more easily.

I KNOW that this opinion contradicts the common one, that marl is not fit for clay grounds. From whence the latter has taken its rise, I know not, if it is not that bodies of such a similar appearance cannot be allowed to benefit one another. But the experience of many counties where marl is used, and where the soil is generally a deep clay, contradicts this vulgar opinion. The following experiment puts it beyond all doubt.

Exp. 39. I filled a pot with clay of the same kind I had used in the former experiments, which had been exposed to the air for four months, and seemed to have no mixture of any other earth with it, as it made good brick, with the addition of sand; and had been taken up seven or eight feet below the surface. This pot I shall call No. 1. Pot No. 2. was filled with equal parts of clay and marl; No. 3. with equal parts of clay and soured lime; No. 4. with equal parts of clay and sea-sand well washed; No. 5. with equal parts of clay
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and dung. These different compositions were turned daily. On the 26th of *April* six grains of barley were sown in each.

May 14. No. 2. had two plants, above ground ; No. 3. had four.

May 17. No. 2. had six ; No. 3. had seven, two of which were from one grain ; No. 4. and 5. had one each.

May 21. No. 1. had five, of which two were an inch and a half high ; No. 2. had six two inches high ; No. 3. were about the same height ; No. 4. had two, one of which was one inch high ; No. 5. had three, each two inches high.

June 4. No. 2. tallest and greenest ; No. 3. very near it ; No. 1. and 5. of an equal height, but the latter of a very light colour ; No. 4. worst of all.

Aug. 20. No. 1. about nine inches tall, and much withered. The roots seem not
to

to have pierced the clay, but to have sunk along the cracks. No. 2. has nine ears, and those of a very deep green colour. No. 3. has eight, but not of so deep a green. No. 4. has five, and those much smaller. No. 5. has nine, almost as good as No. 2. I had no opportunity of seeing them afterwards.

Cor. 1. By this experiment it appears, of what great advantage it is to manure clay; for, of itself, pure clay is not capable of producing good plants, because their roots are not able to penetrate it.

Cor. 2. Sand appears, in opposition to the common opinion, to be the worst manure of those used. It cannot indeed separate the minute particles of the clay, which is the only useful separation for the growth of vegetables. A little sand rather seems to increase the union of the particles of clay, as appears from the manufacture of brick.

Cor. 3. Lime seems to be a good manure for clay. What I used had been soured for some time. The effect which the air has on it, in changing it from quick-lime to effete lime, must open the ground considerably.

Cor. 4. Dung and marl appear to be the best manures for clay. The former has a strong fermentation; the latter loses all cohesion when water is added.

S E C T. VI.

Of vegetation.

IT is worth our pains to take a short view of what must happen to the vegetable food in the vessels of plants. To enter into a discussion of the anatomy of plants, would be foreign to the subject. I shall take that as demonstrated by botanists.

THE nitrous salt being formed on the surface of the soil, will be washed down
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by the dews and rains. It will dissolve what oils it meets with in its way, and constitute with them a saponaceous juice, containing, besides the former principles, fixed air and fixed fire. This juice will be retained in the soil; because I showed by experiment, that fertile soil acted like a sponge with respect to water. This natural descent from gravity, and the natural ascent from the heat of the earth and influence of the sun, must keep the nutritious juice in a continual motion; so that it must be continually applied to the roots of plants destined for the admission of nourishment.

THE first question which can raise any doubt here, is, In what manner do the juices arise to the tops of plants and trees? *Malpighius* thinks, this is owing, in a great measure, to the air-bladders which he discovered in the structure of plants, and which he thought behaved to dilate and contract, according to the different changes of heat and cold which happen in our atmosphere.

mosphere. To me it does not appear, that the dilatation of such vessels would force it more upwards than downwards. I should rather imagine, that such a dilatation would stop the motion altogether.

THE cause commonly ascribed, *viz.* the action of capillary vessels, appears to me sufficient for that end. *Hales* has demonstrated the fact to the eye, by several experiments, in which a part of a branch, being cut at both ends, and having its under part immersed in water, a moisture was immediately perceived in its upper part. This effect of capillary tubes must arise from the attraction betwixt the substance of which they are composed and water.

THE attraction betwixt wood and water appears to be very strong, by an experiment related by *Dr Taylor*, in the *Philosophical Transactions*, No. 368. He hung at a pair of scales a piece of fir board, soaked it in water, weighed it, and then immersed it again in water. To raise this
piece

piece of wood, which had a surface of an inch square, in contact with the water, fifty grains over and above its former weight were required. The additional weight in the different trials, he says, was always proportional to the surface. The distance of the under surface of the board from the surface of the stagnating water, at the time of separation, measured upwards of $\frac{1}{100}$ of an inch. This additional weight is the real measure of the attraction betwixt that surface of wood and water in contact.

THERE is another force that must contribute to raise the sap, *viz.* the natural attraction betwixt the constituent parts of the fluid. This must certainly be the case, when the sap moves quickly, as in the vine in the bleeding season. Both these causes acting, and the evaporation going on continually from the superior parts of the vessels, the sap rises from the roots of the plants to the extremity of their branches.

BUT nature does not intend that this shall be done too quickly. There are many spiral vessels, and many cells into which the sap is deposited, and by which it must be retarded. In these the sap will be much altered in its nature, by the motion of the plants, by the continual motions of the air-vessels, and perhaps by the particles of light taken in at the leaves. The juices are rendered richer by the expulsion of the watery particles. The remaining ones are partly applied to the extremities of the vessels, which run in all directions, horizontally as well as perpendicularly, and make the plant increase in breadth and length; and partly go to the formation of leaves, flowers, fruit, &c.

It is easily conceived how plants, by the different combinations of the five principles of which their food is composed, and the combination of these in different degrees, must differ very much in their juices and products. If their grosser particles are to be separated for any use, the subtiler

tiler are all carried off by lateral vessels, until none are left but what are wanted; if the subtiler particles are to be used, they are to be separated by small vessels fitted to receive them, implanted in the larger, or in the cells where the juices are deposited. In this way particles of any size may be lodged in any part of the plant. Hence all that variety in the salts, oils, and figures of plants. Hence all that variety of smells, tastes, virtues, and other qualities.

How strong the power inherent in the vessels of plants to change and alter those substances which are taken in, appears from an experiment of *Homberg*. He filled two pots of earth mixed with some saltpetre. Into one he put cresses, which is an alkalescent plant, and affords a volatile alkaline salt, but no acid; into the other fennel, which is an acescent plant, and affords an acid on distillation, and no alkaline volatile salt. He filled two other pots with earth, which had all its salts washed

washed out, if there were any in it. Into one he planted fennel, and into the other cresses, as in the former. The two plants in the nitred pots grew much better, and weighed much more than in the pots without nitre. The cresses in the nitred pot, when distilled, gave no acid salt, though fed on a salt which contained an acid. The fennel fed in the washed earth gave an acid, though there was none in the earth. This experiment shows, that the vessels of plants have a power of changing the salts taken in from the earth, into their own particular natural one, probably by combining them with different proportions of water, oil, earth, air, and the particles of light which issue from the sun.

BUT how shall we account for the different external forms of plants? Shall we fly to the immediate hand of the Supreme Being? or, as this ought to be the last step in philosophy, can we find no chymical agents capable of this effect? From many experiments, which show the natural inherent power

power in salts, especially the nitrous kind, to run into vegetations, as they are called, and to take the figure of plants, with branches, leaves, nay even an appearance of fruit, owing to the strong attachment subsisting between them and water, I have often been led to think, that the vegetative power of plants, nay their particular forms of vegetation, were owing to that vegetative power inherent in their salts. In effect, we see that vegetative power strongest when most salt enters their vessels ; that is to say, in the spring.

THUS I have endeavoured to account for the effects of manures on the different soils, and for the rise and changes of the vegetable food in the vessels of plants, from those remarkable attractions and affinities which the Author of all has endued the smaller particles of matter with. These are not, as is commonly imagined, mere passive bodies ; but active, vigorous, and capable of producing those changes by which nature is supported. I have demonstrated

monstrated these affinities by experiment ; I have assumed no other principles ; I have built my whole plan on these ; I hope, therefore, that its simplicity will be a strong proof of its truth.

BUT whence these elective attractions which move the whole ? Whence acquires matter the power of acting without itself ? For that must be the case, unless we suppose an endless chain of material agents. Whence but from an immaterial being, who, by his order, first fixed these properties to matter, and, by his immediate will, constantly supports them in the same tenor ? It is on particles too minute for human eyes, that the omnipotent hand chuses to exert itself, and on their powers to erect this beauteous system. Hence the origin of all motion, adhesion, increase, and organised matter.

BUT as all individual forms were designed to be of finite duration, he established other particles with repulsive powers,
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and mixed the seeds of dissolution with the first rudiments of organical life. While the vessels are pervious, and the motion of the fluids subsists, the attractive overbalance, the repulsive powers, and the vegetable or animal life continues. But when that motion ceases, and other circumstances concur, the repulsive become too strong for the attractive powers, dissolve the composition, and reduce the body to those particles of which it was at first made up. This is the great circle that Omniscience has marked out, and Omnipotence circumscribes itself to, for the greatest good of the whole.



P A R T

PART V.

SECTION I.

Of weeds.

THE last article which we proposed to consider was, what impediments there were to vegetation, and the methods of removing them. These impediments are such as either belong to the soil or to the plants. We shall treat of them according to this division.

AMONGST the impediments of the soil, I class all such vegetables, as, being of no use to the farmer, are called *weeds*, or *inutiles herbæ*. These become hurtful to the growth of more valuable plants, by consuming part of the nourishment. I here class also those roots called *wreck* in this country, which run through the ground often in such plenty, that they bind the

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soil,

foil, hinder the roots of the corn to spread, and draw up a great deal of nourishment. These are generally the roots of the quick grafs. The rest harrow, has a large root which goes very deep.

THESE weeds, and the roots belonging to them, are destroyed, 1. By summer fallowing. They are torn up by the plough when they begin to shoot, their roots are exposed to the sun, they soon wither, and are killed ; or else they are buried below the surface.

2. A METHOD much analogous to the former, is trenching eighteen inches deep. This buries the plants so deep that they die ; but this can only be put in practice where the soil is good to that depth.

3. ANOTHER method of killing useless plants is, to hoe them when young. That effectually roots them out.

4. No

4. No plants can grow without a sufficient quantity of fresh air, which is as necessary to the vegetable life as to the animal. Whatever plants cover the ground closely, destroy all those which grow below. Hence a good crop of pease kills all weeds by overshadowing them ; in so much that the farmer assures himself of a good crop of wheat if the pease are good. If they are not, a greater quantity of weeds comes up than usual ; and he never can expect any of the three following crops to be good, unless he gives the ground a fallowing.

It is in this way, likewise, that fog is destroyed. The inclosure is shut up from the middle of *May* to the beginning of *December*, and then fed from that time to *April*. After that it is sowed for a crop of hay. The fog being so long covered by two succeeding crops of grass, is cut off from the benefit of the air, and so dies.

5. THERE is yet another way of destroying these weeds ; and that is, by marl. I

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have

have seen broom effectually killed by marl. I have seen a crop of wheat growing on a field which was partly marled and partly not. That part of the field on which marl had been laid, was free from all weeds, while the other unmarled part was full of them. The same wheat was sowed over the whole field. I can account for this effect of marl in no other way than this, that the grain is brought up so speedily as to be able to choke and destroy these weeds.

S E C T. II.

Of a wet soil.

THERE is not a greater enemy to vegetation than the too great moisture of the soil. It is always owing either to a stratum of rock, or of clay, generally the latter, below the surface, which not allowing the rains to pass through, they can get off in no other way than by evaporation; a very slow method, when compared to filtration.

filtration. Farmers express the effects of water by saying, that it sours the ground. It is not meant by this, that the ground becomes really acid, but only that it is changed in its nature, and rendered unfit for vegetation. The natural product of this soil are, rushes and four grasses; which last appears in the furrows, but seldom in the crown of the ridge; is dry and tasteless like a chip of wood; and feels rough, when stroked backwards. The natural effect of stagnating water I take to be, its putting an entire stop to the admission, and consequently to the influence of the air.

THIS excess of moisture is carried off by a proper disposition of the furrows, according to the natural descent of the ground, by which the water will have an easy passage to get away. It is likewise material that the furrows should be straight: for the straighter the furrow, the shorter time will the water remain in the ground. It would appear likewise, that the narrower the ridges were made, provided they were a-

bove the stagnating water, the sooner would the water fall through them, to get at the furrow. The furrow should be made with a double mouldboard plough, that both its sides may slope. Marling the ground, as I said before, makes it drier, by opening and loosening the soil. A field manured in this way, will be fit fourteen days sooner in the spring for ploughing. If these methods do not succeed, on account of water arising from springs, open or hollow drains must be made at different distances. Open drains seems best, if the springs be not too many.

S E C T. III.

Of rains.

GREAT rains are considerable impediments to the proper concoction of the juices in the vessels of plants, and alter very much the nature of these juices. Says a *French* author : *En l'année 1705, il ne plu presque pas en Juin et en Juillet, et les bleds*

bleds etoient excellent. Mais en 1707, quoiqu'il y ait eu de chaleurs extraordinaires, il plu si abondamment pendent les deux mois, que le blés n'ont rien valu, et ces sont presque tout échauffés.

It is observed, that all plants grow very fast after rains ; not only the terrestrial, but the equatic. The latter can never be supposed to want water ; so that this effect must proceed from some other cause, than the increase of nourishment by the roots. The same effect is observed to happen, when the sky, from being clear, grows cloudy and stormy. Perhaps their too great perspiration may be stopped : perhaps the moisture is sucked up by the pores of the leaves and wood : perhaps, as their nourishment depends on the circulation of their juices, and that circulation on the contraction of the *tracheæ* or air-vessels, according to *Malpighius*, the sudden contraction fills the smallest and remotest vessels with nourishing juices ; and does it with some force, which may lengthen the vessels. As the
vessels

vessels are more full of water, and the perspiration less than ordinary, it is no wonder that the juices are not well concocted, and the grain bad.

S E C T. IV.

Of faulty seed.

HAVING considered the impediments to vegetation which arise from the ground, let us next take a short view of those which arise from the seed. To produce strong plants, we must chuse strong seed. Grain which has been starved in meagre grounds cannot thrive.

OLD grain will not grow; and, therefore, farmers always chuse the last year's corn. It is thought that grain will not grow when it passes the age of five years: but the time cannot be precisely fixed, for that must depend on the driness and oiliness of the seeds. All the oily seeds keep long,

long, some of which will lie in the earth for fifteen or twenty years. Two months after the great fire in *London* there appeared a great crop of a species of *erysimum*, where there had been houses for a thousand years. Mr *Reaumur* sowed some of the grain which had been preserved in the citadel of *Metz* for one hundred and thirty years ; and which made very good bread. In three weeks some of the grains were swelled, and some not. In six weeks no grains were to be found.

THE cause of sterility in old grains seems to consist in the vessels losing that suppleness which is necessary for their extension, and filling with water ; and in the contained liquor losing that gluiness which is necessary for nutrition. This appears from the brittleness of the grain, which becomes so by the evaporation of the mucilaginous parts.

S E C T V.

Diseases of plants.

ALL organized bodies, consisting of containing vessels, and contained fluids in motion, are subject to have those fluids altered, and that motion vitiated. Hence the diseases of plants. *Tournefort* has, therefore, judiciously classed these diseases into those which arise, 1. from too great an abundance of juice; 2. from too little; 3. from its bad qualities; 4. from its unequal distribution; 5. from external accidents.

Too great abundance of juices must cause stagnations, corruptions, too great a quantity of water-shoots, varices, cariosities, &c. It seems to be in this way that too much rain operates. The smut, which is a corruption of the grain, ought to be classed here; because it happens most to weak grain, and in rainy seasons. It may, likewise,

wife, be communicated by infection, if I may so speak ; and the smut, like other contagious diseases, may be transmitted from the infected to the healthful grain. The experiment, I was informed, has been tried. Some smutty grain was sown along with very good seed ; and the produce appeared very smutty. Nor ought it to surprize us, that this should happen to the juices of plants, when we find, by daily experience, that the juices of animals assume the nature of the contagious ferment communicated to them. This disease is prevented, in a great measure, by steeping the grain in a pickle of sea-salt. This operates in two ways. It strengthens the seed, and fits it for expelling the superabundant watery juices ; and, by its great weight, suspends all the faulty grain ; so that none but the heaviest and strongest fall to the bottom, and are made use of.

DUNG seems to prevent other diseases arising from too great a quantity of moisture. An experiment, performed by a gentleman

gentleman of my acquaintance, will shew this effect of dung in a strong light. He fallowed two acres of poor ground, which had never got any manure, with a design to sow wheat on it; but altering his scheme afterwards, he laid some dung on a small part of it, and sowed the whole, after it had got five furrows, with barley. A great quantity of rain fell. The barley, on that part which was dunged, was very good; but what was on the rest of the field turned yellow after the rains, and when ripe, was not worth the expence of reaping. This experiment shows, that the moisture and poverty of the soil was the cause, and that the dung was the cure of this disease.

PLANTS and trees certainly decay for want of proper nourishment. This is the cause why the leaves fall off at the approach of winter. It appears plainly from the following experiment. Ingraft an almond tree on the black damask plumb: for the first year the almond tree thrives very well; but after that they both decay slowly and die.

die. The reason is, because the former vegetates much sooner than the latter; and, therefore, requires nourishing juice when the former has it not. While young, it is easily supplied; but when it grows larger, it exhausts the plumb, and is starved itself. If the plumb is ingrafted on the almond, the juice rises in the latter, when the former is not fitted to receive it, and it dies of repletion.

DU HAMEL, in *Mem. acad. des sciences* for the year 1728, mentions a disease, called *le mort*, which attacks the saffron in the spring; and is owing to a plant of the species of trefoils, that has no stem, fixing some violet-coloured threads, which are its roots, to the roots of the saffron, and sucking out its juice. This disease is prevented by digging a trench, which saves all the unaffected. All diseases from defect of nourishment, are cured by the application of manures.

THE juices may be, likewise, faulty from their bad quality. When the turpentine juices of the pine and fir turn too thick, the tree is suffocated. Sugar canes, it is said, do not thrive so well in rich new soil, because it affords too oily a juice, which is not so good for sugar : if they are cut when six months old, the leaves burnt, and the ashes laid round them, they afford better sugar. The alkaline salt, from the ashes of the leaves, attenuates the oils, and makes a better saccharine juice. Plants or feeds transported from warmer countries to cold, decay gradually, because the juices are not sufficiently attenuated for want of heat.

THE unequal distribution of the juices seems to be another cause of vegetable diseases. In corn, the juice sometimes runs too much to the leaves ; cutting or eating the corn is a remedy for this, as it sends the juice to the stalk.

EXTERNAL accidents, such as frost, hail, flies and their eggs, vermin, &c. give rise
to

to many diseases. There is a small white hard worm very common in new ground, which destroys plants by eating their roots. These worms are killed by quick-lime or lime-water.

THE mildew is to be ranked here, as it seems to be owing to a gluy saccharine matter falling with a summer shower, and blocking up the perspiration of the plant. This matter may be felt and tasted on the surface of the leaves. That it operates in this way, appears from the following fact. There is in the *Briançon*, a species of nut-tree, which has all its leaves covered with a saccharine substance, arising from the perspiration of the juices of the plant. If it is in very great quantity, the trees often die.

AMONGST the class of external accidents we may place the effects which arise from the contiguity of certain plants. There are some plants which do not thrive in the neighbourhood of others. This is observ-

ed of the cabbage and cyclamens, of hemlock and rue, of reeds and fern. We have many examples of such like antipathies amongst animals. These effects seem to be produced by the effluvia which are emitted by all organised bodies.

IT is surprising, that the present subject, so highly necessary to the proper culture of plants, should have been almost entirely neglected; so that an inquirer finds too few facts and observations to be able to lay down any regular system. Besides, the diseases of vegetables seem to require more assistance, and therefore demand more attention, than those of animals; if we regard the cure alone, and set aside the higher rank in the scale of creation, and consequently the higher value of the latter. Animals have a sentient power within, which, irritated by the cause of a disease, quickens the motions of the heart and arteries, and continues these mechanical agents till the morbid particles are expelled, or the animal system overpowered by them. But there
is

is no such power inherent in vegetables. Unless a remedy is applied from without, they must continue to labour under the disease. Whoever removes the disease of an animal, does it by directing these natural and mechanical motions aright, and in the way that the motive power seems to point out. But whoever removes a vegetable disease, must look on the work as entirely his own, as he has got no assistance from the vegetable itself.

S E C T. VI.

Plan for the further improvement of Agriculture.

THUS I have endeavoured to show, that agriculture is not so uncertain and unscientific an art as is commonly thought; but is reducible, like other arts, to fixed unalterable principles. I have already looked back, and considered the impediments which have lain in the way of its progress

to some degree of perfection. I shall now look forward to see how these may be best remedied, and in what manner we can assist it in its progress.

AGRICULTURE does not take its rise originally from reason, but from fact and experience. It is a branch of natural philosophy, and can only be improved from the knowledge of facts, as they happen in nature. It is by attending to these facts that the other branches of natural philosophy have been so much advanced during these two last ages. Medicine has attained its present perfection only from the history of diseases and cases delivered down. Chymistry is now reduced to a regular system, by the means of experiments made either by chance or design. But where are the experiments in agriculture to answer this purpose? When I look round for such, I can find few or none *. There, then, lies the

* Since these papers were wrote, I have read three volumes of experiments published by *Du Hamel* on *Tull's* system of agriculture. They are distinct, exact,

the impediment in the way of agriculture. Books in that art we are not deficient in; but the book which we want is a book of experiments.

AND, indeed, as things stand at present, it must always be so. Mankind are shy in attempting any thing, or at least rendering it public, unless they can make it complete, or erect some plausible system. This they may do in all other arts, but they cannot in agriculture. The time so seldom comes about, and the progress of the experiment is so slow, that one person can make but very few during his life. A number of experiments are to be found, not in the possession of one, but in the hands of many. The fault, then, lies not in the deficiency of facts; for chance and design must have been able to furnish many;

exact, conclusive so far as they have gone, and stand a model for experiments in agriculture. What a shame for *Great Britain*, where agriculture is so much cultivated, and where that system took its rise, to leave its exact value to be determined by foreigners!

many ; but of a certain, proper, and easy channel, through which they might be conveyed to the world, without wounding the natural vanity of mankind.

HITHERTO these facts and experiments have been confined to conversation alone, and have died along with those who made them. I would propose a simple remedy for this. Let a committee of the *Edinburgh* society, not exceeding five persons, be named for the branch of agriculture alone, whose duty shall be, to receive single and detached experiments, put them in a proper dress, if they stand in need of it, and publish them to the world at stated times, like a public paper. This manner of appearing seems well calculated to raise a spirit of experimental farming over the country.

THE narrator, on his part, should deliver the experiment in the plainest and most distinct manner, and separate the facts from his reasonings. Perspecuity and exactness are the chief beauties in experimental

mental writing. The plain fact should be first told, with all its concomitant circumstances ; such as, the situation of the ground, nature of the soil, previous culture of it, quality of the seed, country where the experiment is made, state of the air, at sowing and after, with regard to heat and cold, drought and rain, wind, &c. The reasoning on the experiment should then follow, and should be such as arises naturally from the experiment. Although it is not necessary to mention any name to the public, yet the experiment, when delivered, should be subscribed by the person who made it, to avoid all imposition.

IN order to increase the spirit of experiment-making over the country, I would purpose, that this committee should have it in their power, to grant one or more honorary or lucrative premiums, to those who shall have delivered the most ingenious and useful experiments in agriculture. It is in this way, I think, that the premiums

premiums designed for agriculture should be established. They ought to be, not on such subjects as the farmer is naturally led by his own gain to pursue; for such he will generally follow, to the utmost of his knowledge and abilities; but on such as are not so nearly connected with gain, and make him go out of the common road. This confinement may, however, be too great at the first setting out; and it may be more advisable, to admit all experiments for some time, till the spirit be once raised.

THE happy consequences of this scheme are very evident. Farmers will begin to see the only method of cultivating this art with success; they will attend to minute circumstances to which they never did before; they will be fond to communicate the issue of their experiments to the public, when they can do it in that easy and concealed way; they will have a dictionary of facts to consult upon occasion; and
will

will be able to draw advantage from both the good and bad success of others.

IN time this plan may afford fund sufficient for some future comprehensive genius, who, laying the different, and often seemingly opposite experiments together, and considering all their concomitant circumstances, may be able to reduce the practice to fixed and permanent rules. This good fortune seldom happens to the first experimenters in any art; for they see things in too narrow a view, and often with too prepossessed a mind. It is reserved for that unbiassed and sound judgment, which can take from every opinion whatever truth it contains; and from the whole united together, raise one regular, beneficial, and lasting system.

F I N I S.